

The
AMSAT®
Journal



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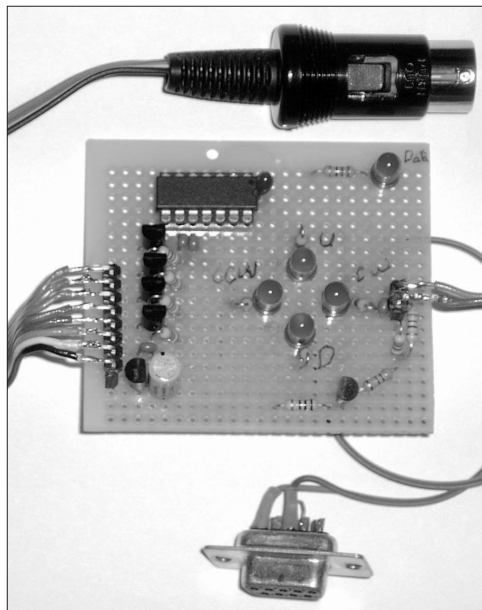
Volume 29, Number 3

May/June 2006



AMSAT's youngest member - her name is Fred. (?) See page 14.

Ready for some new rotor control hardware/software? See page 4!



AMSAT-NA
850 Sligo Avenue, Suite 600
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Periodicals

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AMSAT Announcements

TAPR Call for Papers

Technical papers are solicited for presentation at the 25th Annual ARRL and TAPR Digital Communications Conference to be held September 15-17, 2006 in Tucson, Arizona. These papers will also be published in the Conference Proceedings (you do NOT need to attend the conference to have your paper included in the Proceedings). The submission deadline is July 31, 2006. Please send papers to:

Maty Weinberg
ARRL
225 Main St.
Newington, CT 06111

or you can make your submission via e-mail to: maty@arrl.org Papers will be published exactly as submitted and authors will retain all rights.

73,
Steve Ford, WB8IMY

Joel Harrison, W5ZN, the new ARRL President, is shown with Rick Hambly, W2GPS, renewing his AMSAT membership at the AMSAT booth at the Dayton Hamvention.



AMSAT's Mission

AMSAT is a non-profit volunteer organization which designs, builds and operates experimental satellites and promotes space education. We work in partnership with government, industry, educational institutions and fellow Amateur Radio societies. We encourage technical and scientific innovation, and promote the training and development of skilled satellite and ground system designers and operators.

AMSAT's Vision

Our Vision is to deploy high earth orbit satellite systems that offer daily coverage by 2009 and continuous coverage by 2012. AMSAT will continue active participation in human space missions and support a stream of LEO satellites developed in cooperation with the educational community and other amateur satellite groups.





Radio Amateur Satellite Corporation (AMSAT-NA)
 850 Sligo Ave., Silver Spring, MD 20910-4703
 Telephone: 301-589-6062 – Toll Free: 888-322-6728
 Facsimile: 301-608-3410
 AMSAT-NA Club Callsign: W3ZM
 AMSAT-NA Web site: <http://www.amsat.org>

The AMSAT Journal Staff

Editor-in-Chief: Ed Long, WA4SWJ
 (wa4swj@amsat.org)

Circulation: Martha Saragovitz
 (martha@amsat.org)

Editorial Staff:
 Bill Hook, W3QBC
 Lee Herterich, K1VZI

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Editorial Office: Ed Long, WA4SWJ, 6685 Southeast 108th Street, Belleview, FL, 34420-3449, e-mail Journal@amsat.org, telephone: 262-374-1349. **Advertising Office:** AMSAT-NA Headquarters, 850 Sligo Avenue, Suite 600, Silver Spring, MD 20910-4703.

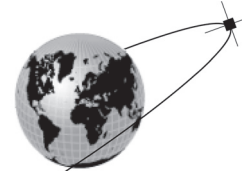
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The AMSAT Journal staff is always interested in article submissions. Whenever possible, submissions should be sent via e-mail to journal@amsat.org using plain text or word processor files; photos or figures in TIF, GIF or JPEG formats. AMSAT-NA reserves the right to select material for *The AMSAT Journal* based on suitability of content and space considerations. The editors of this publication are volunteers giving freely of their talents, time and efforts to produce *The AMSAT Journal*.

APOGEE VIEW

by Rick Hambly, W2GPS • w2gps@amsat.org



DAYTON 2006

The Dayton Hamvention 2006 is over. Thanks to the many AMSAT volunteers who helped set up, run the booth, make presentations at the forums, run the live satellite demonstrations and tear down the booth area for their many hours of selfless dedication to AMSAT and their contribution to the great success of AMSAT's activities at Dayton this year. Special thanks go to our new Hamvention coordinator Gould Smith, WA4SXM, and our local Dayton coordinators Ed Collins, N8NUY, and Nancy Makley, KC8GYW. Thanks also to the many members who came by to renew their memberships, buy products, make contributions, join the President's Club or just hang around and talk about their AMSAT activities.

This year AMSAT expanded our presence at Dayton by expanding our booth, lengthening our Forum session, adding an AMSAT Educator's Forum and expanding our live satellite demonstrations. The expanded booth area contained:

- A "slide show" of the AMSAT satellite archives and other presentation materials;
- A demonstration of a new power storage system using a super-capacitor and a single-cell "battery" charge regulator;
- A demonstration of the Eagle mode U/V Software Defined Transponder (SDX), based on a TMS320C6713 DSP chip.

The expanded time for our forum gave presenters a better opportunity to present our messages that the P3E and Eagle high orbit satellite projects are progressing at a good pace, that AMSAT's AO-51 satellite ("Echo") is still working perfectly and is easy to use, that the AMSAT/ARISS human spaceflight program continues to provide valuable and exciting services, and that AMSAT has established a new education initiative.

Next year we will add to our presence at Dayton with a joint AMSAT/TAPR banquet on Friday night. Tentatively, the banquet will be at the Wright Patterson Air Force Museum. Finally you won't have to make the difficult choice of which banquet to attend!

2006 Space Symposium

For those of you who attended the Dayton Hamvention and missed some of the events or want a more focused, in-depth exposure to the world of AMSAT, now is the time to begin planning for the AMSAT 2006 Space

Symposium and Annual Meeting that will be held in October 2006 at the Crowne Plaza Hotel near San Francisco. Everyone is invited any or all of the events spanning Thursday through Tuesday (Oct 5th-10th), which include:

- AMSAT Board Meeting, 8 AM Thursday through noon Friday;
- AMSAT Space Symposium General Meeting, 1 PM Friday through 11 AM Sunday;
- The President's Club reception, Friday evening;
- The Annual Banquet, Saturday evening;
- An organized tour, Sunday afternoon;
- The ARISS International Delegates Meeting, Monday and Tuesday.

For more information see the AMSAT Web site at www.amsat.org and click on the 2006 *Space Symposium* icon on the left column or call Martha at the AMSAT office at (301) 589-6062.

Other Events and Activities

By the time you read this I hope to have met with many of you at the Rochester, NY Hamfest (June 2-4) or the Eagle Digital Design Meeting in San Diego (June 29-30) or the 21st AMSAT-UK Colloquium at the University of Surrey, Guildford, UK (July 28-30).

This is going to be an exciting year with AMSAT-NA working on Eagle, AMSAT-UK working on the SSETI European Student Earth Orbiter (ESEO) project, AMSAT-DL working on P3E (with substantial assistance from AMSAT-UK and AMSAT-NA) and other projects in the works at AMSAT groups around the world. Visit the AMSAT Web site often for the latest news and status.

AMSAT Needs You!

At the risk of being repetitive, AMSAT needs your support to achieve our goals. We must raise a minimum of \$150,000 in 2006 just for the Eagle project. Please encourage other Hams to join AMSAT. If you can, make a tax-deductible donation at the AMSAT Web site or call Martha in the office at (301) 589-6062. Donations of \$120.00 or more qualify for President's Club status. Your generous contribution to AMSAT will help ensure that our common dreams will become reality.

continued on page 5 ...



Simple Satellite Tracker Interface for Yaesu G5500 or G5400 Rotors

by Mark Spencer, WA8SME, mspencer@arrl.org

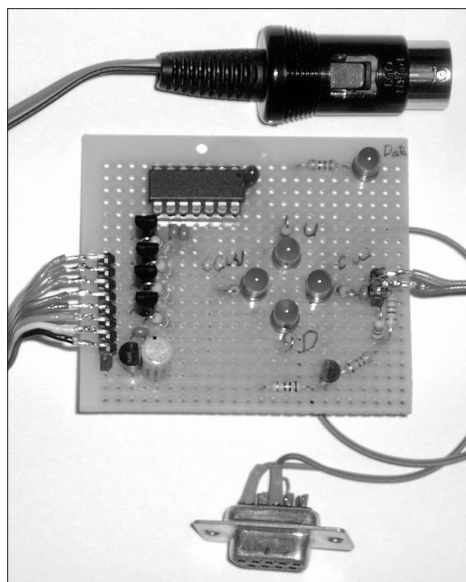
In the September 2005 *QST* article "A Satellite Tracker Interface", I described a simple interface that connects the Yaesu G5500 rotor system to a computer running either the NOVA[1] or SatPC32[2] satellite tracking software to automatically point satellite antennas. My motivation for that project was to illustrate a relatively inexpensive interface system that schools could duplicate to satisfy one of the station requirements to qualify for an ARISS contact. I also wanted to illustrate a project that hams and students alike could use to learn about microcontroller programming. Readers of that article suggested two things:

1. The interface should also work with the Yaesu G5400 rotor system.
2. Make the interface even less expensive.

In this article I describe a second version of the interface to address those two suggestions. I also had the self-serving goal of meeting a new programming challenge and learning experience. The result described here is an interface that costs approximately \$20.00 in parts (Table 1) and will work with both the G5500 and G5400 rotors. The hand wired circuit is shown in Picture 1.

Hardware

The circuit depicted in Figure 1 is based on the 16F688 PIC (programmable interface controller). The 16F688 features a universal asynchronous receiver transmitter (USART)



Picture 1: Tracker hardware constructed in breadboard format.

for serial communications, 10-bit analog to digital converters (ADC) for reading rotor position voltages and 12 input/output (IO) ports for control signals. The voltage source for the interface comes from the rotor controller and is regulated down to 5 volts by the 78L05 regulator. Transistor Q1 converts the RS232 voltages from the computer serial port to TTL levels needed to communicate with the PIC. The transistors Q2 through Q5 do the switching of the rotor direction control relays in the rotor controller. The LED's in the circuit are not required for proper circuit operation but do provide helpful information when the interface is operating. The capacitors C4 through C6 provide some filtering of noise on the RS232 and the ADC lines. Of course, it all is controlled by the software inside the PIC.

Software

Programming the PIC in assembly language certainly met my goal of a programming challenge, particularly doing the required binary math to convert degrees into equivalent ADC readings. The software is available to anyone for the price of an e-mail request to mspencer@arrl.org. I have attempted to liberally comment the software to allow the reader to follow the logic. The following are the basic steps accomplished to turn a command from the tracking software to point the antenna into the actions required to move the antenna:

1. Read the antenna position commanded by the NOVA or SatPC32 software. These software packages use the EASYCOM1 [3] protocol. Table 2 is an example of the ASCII command strings sent by the software packages.
2. Convert the commanded

antenna position in degrees to equivalent position voltage in digital form.

3. Read the current antenna position with the ADC.
4. Compare the desired position with the current position.
5. Determine the rotor movement direction to correct for position error (if any).
6. Move the rotors.
7. Keep reading the antenna position and continue to move the rotors until the desired antenna position is achieved.
8. Start the process over again by reading the new position command from the controlling program.

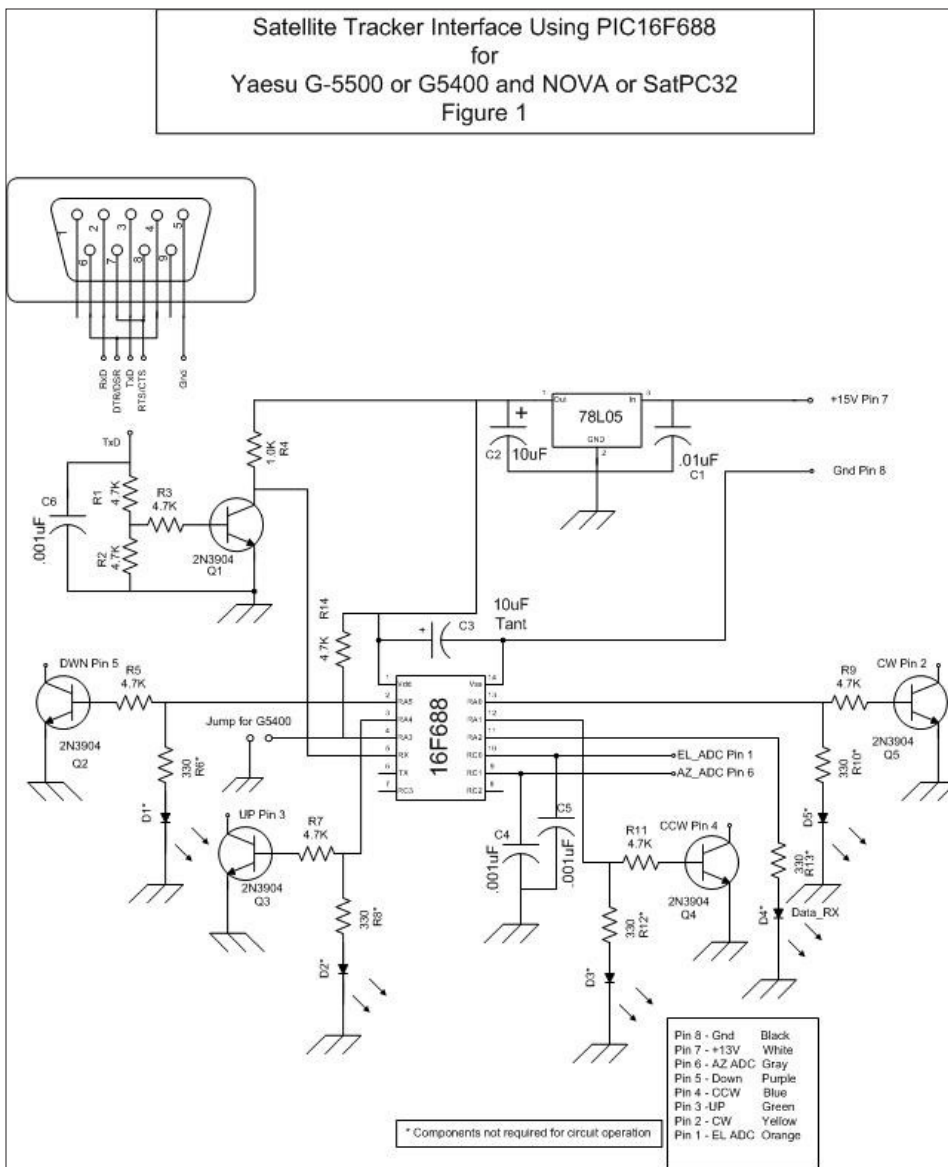
Operation

The interface set-up and operation is pretty transparent. The PIC is programmed to operate at the standard of 9600 Baud, so the NOVA and SatPC32 should be set up for the appropriate COM port and baud rate. Set NOVA to use the EasyComm 1 rotor interface. Set SatPC32 to use the SAEBRTrackBox rotor interface. Set the rotor azimuth stop position (north or south)

Table 1: SatTracker 688 Parts List

Number Required	Part Designation	Part Description	DigiKey
1	U2	PIC	PIC16F688-I/P-ND
1	U1	5 Volt Reg	296-1365-1-ND
5	D1, D2, D3, D4, D5	Red LED	67-1105-nd
5	Q1, Q2, Q3, Q4, Q5	2N3904	2N3904FS-ND
5	R6, R8, R10, R12, R13	330 Ohm	P330BACT-ND
1	R4	1K Ohm	P1.0KBACT-ND
8	R1, R2, R3, R5, R7, R9, R11, R14	4.7K Ohm	P4.7KBACT-ND
1	C1	.01uF	P4582-ND
1	C2	10uF Electrolytic	P1176-ND
1	C3	10uF Tantalum	478-1840-ND
3	C4,C5, C6	.001Uf	P4551-ND
1	J3	9-Pin Serial	A2100-ND
1	J1	6-Pin Female	WM2004-ND
1	J2	8-Pin Female	WM2006-ND
1	J1A	6-Pin Male	WM4304-ND
1	J2A	8-Pin Male	WM4306-ND
14		Pins	WM1114-ND
1	Socket	14-Pin DIP	ED3114-ND





as appropriate for your rotor system. Set the elevation stop position to 0° and 180°. Adjust the software pacing to meet your particular operating conditions. I can provide screen capture documentation to help you set up your NOVA or SatPC32 software upon request.

When you select a satellite for tracking and turn on your rotor controller, you will see the data LED light up when data is being received from the controlling program. When the data light goes out, the direction LED's will light in-turn to indicate that the signals to close the appropriate rotor control relay are being sent to the rotor controller (you will hear the relays close with a audible click). When the antenna has reached the commanded position, the LED's will go out and the relays opened. This process will continue for the duration of the satellite pass.

So if you are looking for a simple project to build to enhance your satellite operation, if you are looking for a programming challenge or if you just wanted to beat the high price of a commercial controller interface, this project might be for you. I encourage you to contact me if you have questions or comments. E-mail me at m Spencer@arrl.org or phone 530-495-9150 (PST), or mail at 774 Eastside Rd., Coleville, CA 96107.

References

- [1] www.nlsa.com/
- [2] www.dk1tb.de/
- [3] www.mustbeart.com/software/easycomm.txt

Table 2: Program Command Outputs

NOVA:

AZ317.4 EL180.0 UP3.56630275 XXX DN000000000 XXX

SatPC32:

AZ360.0 EL000.0

Apogee View - continued from page 3 ...

Please volunteer to set up or work in an AMSAT booth at your local hamfest. Join the Field Operations team. Give a presentation at your local ham club. For more information contact me, the AMSAT office or any of your AMSAT officers and Board members by using the Web site's message forms (click on "About AMSAT" then "Our Leadership Team" then click on any name).

73,
Richard M. Hambly, W2GPS
AMSAT President



The Delfi-C3 Student Nanosatellite

Delfi-C3 Team[6], info@delfic3.nl

Delft University of Technology, The Netherlands, www.delfic3.nl

Abstract

Delfi-C3 is a student nanosatellite developed at Delft University of Technology by a group of students from the faculty of Aerospace Engineering and the faculty of Electrical Engineering, Mathematics and Computer Science. It will act as a technology test-bed for three payloads: Thin Film Solar Cells, an Autonomous Wireless Sun Sensor and an Advanced Transceiver.

Delfi-C3 will make use of the Amateur Radio frequency bands for its telemetry downlink and telecommand uplink. Software will be made available to participating Amateur Radio operators, which will allow them to decode, display and send the telemetry to the central ground station in Delft. As a return favor, Delfi-C3 will include a low power mode-UV linear transponder with a bandwidth of 40 kHz to enable amateurs around the world to communicate with each other.

The satellite will not include an active attitude control system; passive rotation rate damping will be used though to limit the rotation rate. Furthermore, the spacecraft will not be operational in eclipse because the primary payloads do not require it to be. Because of this, Delfi-C3 will not incorporate a battery. Delfi-C3 is scheduled for a piggyback launch by the end of 2006.

I. INTRODUCTION

The idea for Delfi-C3 originated from the desire of Dutch Space to have an early flight opportunity for innovative thin film solar cells. The main objective of the space mission is to measure the characteristic

current-voltage (I-V) curves of eight of these solar cells as a function of operating temperature and angle of incidence of the solar radiation.

Other candidate payloads were collected from the MISAT program [3], [4], a five-year program starting in 2005 to develop micro and nanosatellites that demonstrate a wide range of such applications for use in spacecraft. From this program, two applications were selected to be flown on the Delfi-C3 mission: an autonomous Sun sensor with its own power supply and wireless data connection (TNO Science and Industry), and a high efficiency Advanced Transceiver (TU Delft EEMCS).

The transceiver is used to receive commands from the Delfi ground station and transmit measurement and housekeeping data back to the ground segment. There will be no on-board data storage; so all measured data will be transmitted to the ground segment instantly. The satellite will make use of Amateur Radio frequencies, so the transceiver will be compatible with current amateur standards.

Besides the technical mission objectives mentioned before, the Delfi-C3 project has educational objectives as well. Delfi-C3 is a masters degree thesis project, its main educational objective is to provide MSci students as a team the opportunity to gain hands-on interdisciplinary engineering experience with the design and realization of both the mission requirements and systems of a satellite by providing a challenging real-world application.

I. MISSION CONCEPT AND HIGH-LEVEL REQUIREMENTS

Important high-level system requirements dictate that the thin film solar cells (TFSC's) shall not be body-mounted due to thermal constraints. Temperature range requirements are mainly dictated by the autonomous sun sensor's temperature range. These and other requirements led to the decision to use a 3-unit CubeSat measuring 100x100x325 mm as the structural basis for Delfi-C3. The TFSC's thermal constraints necessitate a configuration with four deployable panels, each containing a frame with an array of two TFSC's and five GaAs-cells as the satellite's power supply. Furthermore, the design does not incorporate a battery. Since the TFSC and Autonomous Wireless Sun Sensor (AWSS) payloads depend on the presence of solar radiation, there is no need for the satellite to be operational in eclipse. This avoids the additional complexity that is involved with using a battery. Finally, the satellite will have a redundant architecture to ensure that the mission does not depend on the new technologies flown.

Since the Delfi-C3 satellite adheres to the CubeSat standard, this implies the use of the Poly Picosatellite Orbital Deployer (P-POD). The P-POD is the standard deployment mechanism for CubeSats. The P-POD was designed at California Polytechnic Institute as a reliable and cost effective deployment system, which can be mounted on most current launchers like the Eurokott Launch Vehicle and the DNEPR.

The P-POD is basically an aluminum box with a spring-loaded door. A maximum of

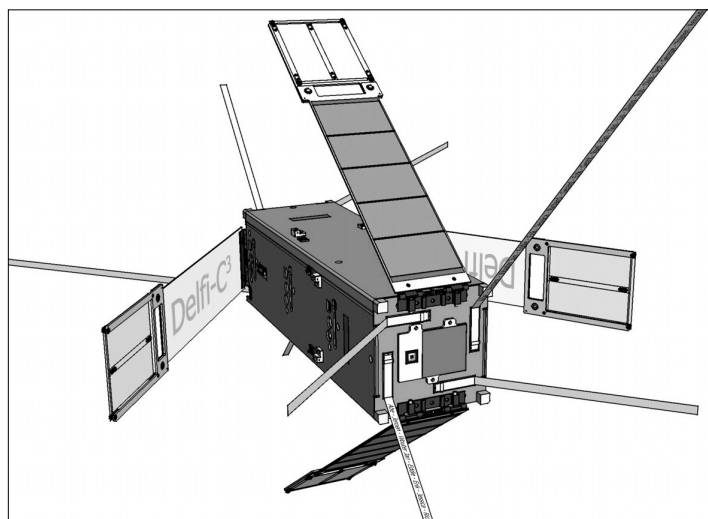


Figure 1: The Delfi C3 satellite.

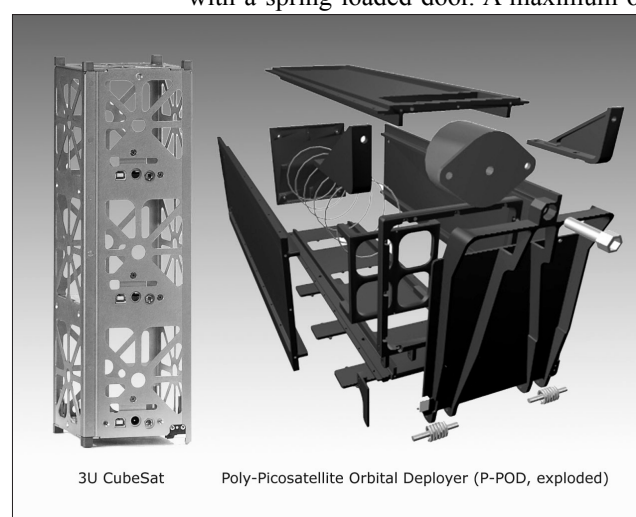


Figure 2: The 3-unit CubeSat structure and the P-POD (Source: Cal Poly).

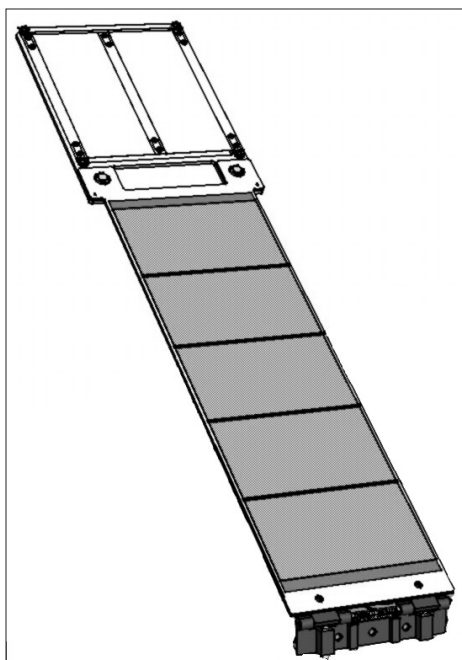


Figure 3: GaAs panel and TFSC payload.

three 1-unit CubeSats or one 3-unit CubeSat can be accommodated in the P-POD. The satellites are ejected from the P-POD by means of a large spring-loaded plunger, giving the satellite an exit velocity of 2 m/s [1]. The CubeSats are kept in position by means of Teflon-coated guide rails. The use of these guide rails creates an envelope between the P-POD wall and structure that can be used to store solar panels or other deployable systems. The walls of the P-POD cannot be used as a hold-down system for the deployables themselves, they need to have their own hold-down system that is activated some time after ejection out of the P-POD.

II. SUBSYSTEM OVERVIEW

A. Structure and Mechanisms

The satellite's structure is based on the 3-Unit CubeSat structure (Figure 2) from Pumpkin, Inc., USA [2]. The structure is made of an aluminum alloy, which has been alodined on all surfaces to make the structure conductive. Furthermore, it has feet on both the top and bottom surfaces providing the mechanical interface with the P-POD. The four solar panels of the satellite are deployed to an angle of 35 degrees with respect to the body, which is the optimum angle to guarantee the required minimum power provision in any attitude. Each panel is 325 mm long, 85 mm wide and is made of 1.5 mm thick carbon fiber reinforced plastic (CFRP). The TFSC payload is placed at the end of the panel in a frame. While in the P-POD, the panels will be held down by using synthetic wire. Melting these wires deploys

the solar panels. A spring mechanism at the hinge of the panel ensures deployment to the desired 35-degree angle. The deployment status of the solar panels will be verified by means of microswitches at the back of the panels.

Eight tape measure whip antennas (Figure

to the other subsystems.

C. Command and Data Handling System

The Command and Data Handling System (CDHS) is designed around an ultra-low power Texas Instruments MSP430 microcontroller, which is embedded in

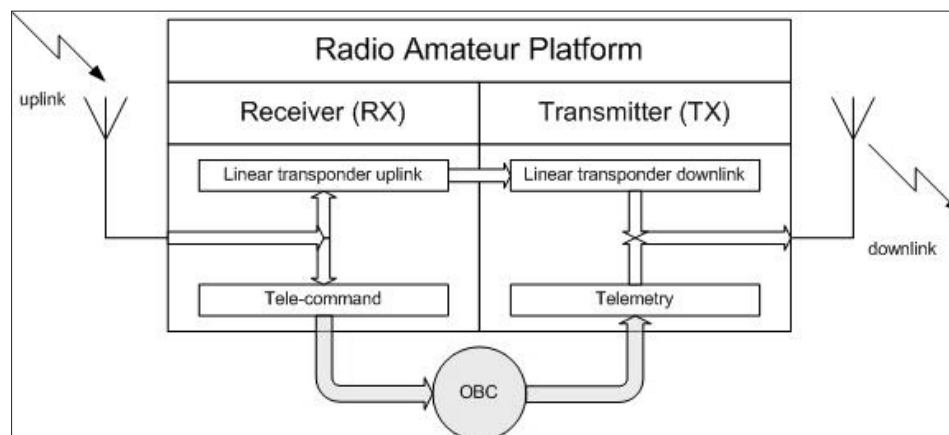


Figure 4: Amateur Radio platform.

7) are used on the satellite; four on the top surface and four on the bottom surface to create a near omni-directional pattern. The antennas are mounted at 45-degree angles with respect to the satellite body. Two of the antennas on each surface are used for the downlink and the other two are used for the uplink. The uplink antennas have a length of 18 cm. The downlink antennas have a length of 50 cm, which is longer than the structure itself. For the antenna deployment, so-called "Modular Antenna Boxes" have been designed to stow the antennas during launch. Deployment is accomplished by melting a synthetic wire by means of electrical heating. The design of the boxes is such that the antennas will unroll and deploy at the desired 45-degree angle.

B. Electrical Power Subsystem

The Electrical Power Subsystem (EPS) has to be able to provide sufficient power to the subsystems under all possible satellite attitudes. There will be a provision for power buffering to be able to avoid continuous initialization of the on-board computer in case of failure of one complete solar panel. This buffering may also compensate for the fluctuation in available power as a result of the satellite's tumbling motion. The four solar panels accommodate five triple junction gallium arsenide (GaAs) solar cells, delivering a minimum power of 2.5 W. Power from these cells is converted by the EPS to provide 12 volts DC to the communications subsystem, and 5 volts DC

the flight microcontroller unit board. The microcontroller and the board are both supplied by Pumpkin, Inc. as part of the CubeSat kit. The connections from the CDHS to the other subsystems will be organized according to a star architecture, making the CDHS the central subsystem of the satellite. The main functions of the CHDS are collecting mission and science data for transmission to the ground stations, controlling the deployment of the antennas and solar panels, providing the ability to execute commands that have been uploaded from the ground station and providing some measure of robustness to cope with failing subsystems.

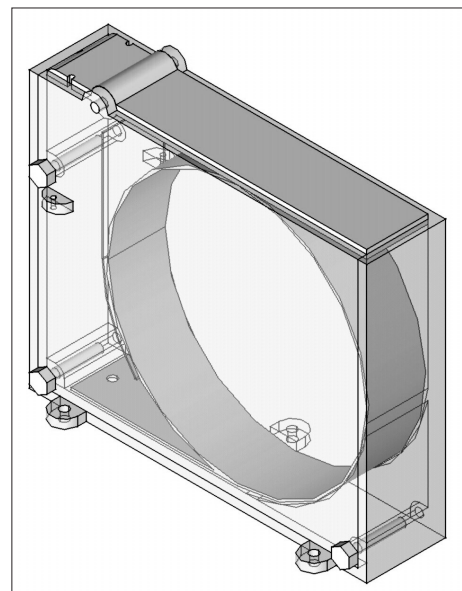


Figure 5: Modular Antenna Box concept.



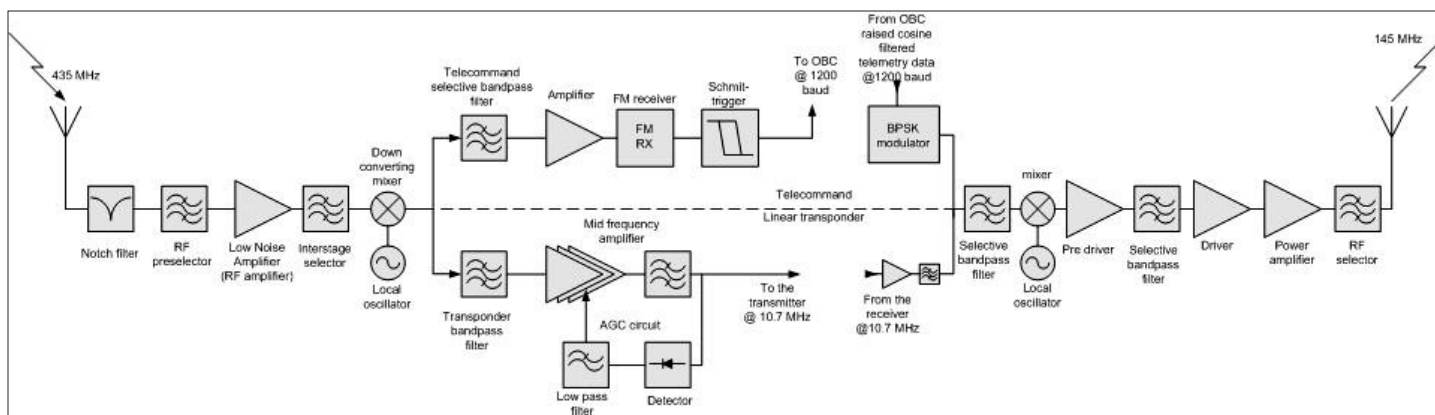


Figure 6: Amateur Radio platform conceptual layout.

The software running on the microcontroller will be supported by the SALVO real-time operating system (RTOS), which is also provided as a part of the CubeSat kit. The SALVO RTOS was developed by Pumpkin, Inc. to run in environments where little memory is available, while still providing support for multi-tasking and events to developers. The software will be flexible but only in a limited fashion, allowing the ground team to change certain parameters but not the actual code itself.

For redundancy reasons, the CDHS incorporates a backup system that has been kept as simple as possible. Redundancy for antenna and solar panel deployment control will reside in the EPS, and the On-Board Computer (OBC) will be provided with an external watchdog. In case of irreversible OBC failure, the data from the Thin Film Solar Cell experiment will be converted for downlink by an analog system. An analog multiplexer will feed the measurement data (voltages) into a voltage-controlled

oscillator that is built using discrete components. It will generate an audio tone with a frequency that is proportional to the measured voltage from the TFSC payload, which can easily be decoded on the ground. The Radio Amateur Platform (RAP) will provide the downlink.

D. Communications Subsystem

The communications subsystem (COMMS) will perform two functions. First, it will provide the telemetry downlink and telecommand uplink functionality. Besides that, it will provide the aforementioned linear transponder service that can be used by Amateur Radio operators to communicate with each other. The satellite will have an uplink in the UHF amateur satellite frequency band (435-438 MHz) and a downlink in the VHF Amateur Radio satellite band (145.8-146.0 MHz). Telemetry downlink will be done using 1200 bit/s BPSK modulation, using the amateur standard AX.25 protocol. The COMMS consists of two redundant systems, the Advanced Transceiver (ATRX) payload the RAP. The Advanced Transceiver payload will be discussed in section V. The RAP functions as a backup option for the Advanced Transceiver. It is built using standard commercial off-the-shelf (COTS) components, providing telemetry, telecommand and linear transponder functionality. Such a platform is a proven concept; it has flown on many amateur satellites before. The linear transponder will relay a 40 kHz wide pass band from UHF to VHF. This provides a very flexible system, which can be used by amateurs using a wide variety of modulation schemes. Furthermore, the linear transponder can be used for Doppler tracking to accurately determine the satellite's orbital parameters. Last but not least, a linear transponder can easily be combined with a telemetry downlink.

The Amateur Radio platform receive section converts the received RF to an intermediate frequency of 10.7 MHz where the signal will be split between the command receiver (FM receiver chip) and the linear transponder IF section. The telecommand uplink modulation scheme will be 1200 baud Manchester FSK as used on AO-16. This allows the use of a

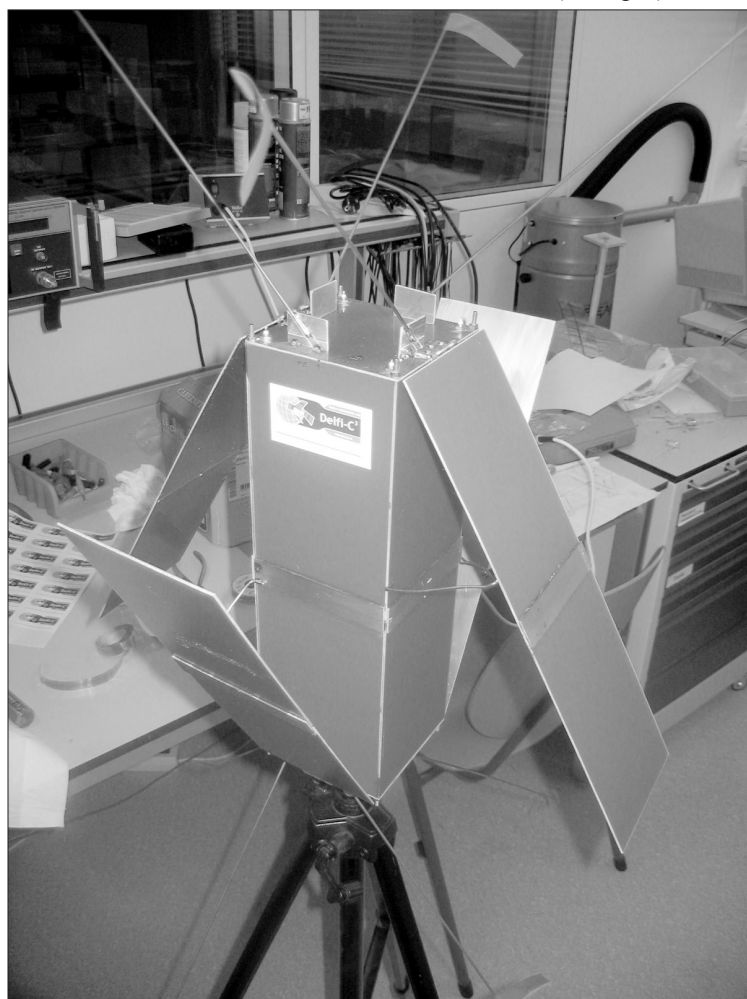


Figure 7: Delfi-C3 antenna model.



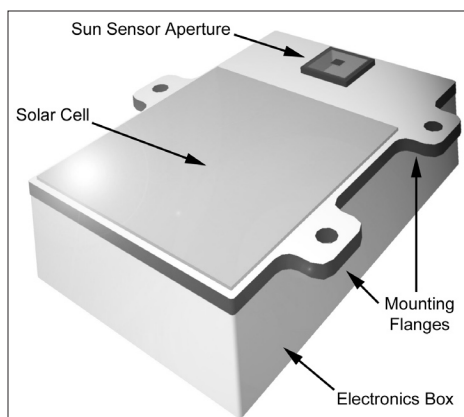


Figure 9: Autonomous wireless sun sensor.

simple FM receiver chip that has the added advantage of providing an uplink that is Doppler tolerant to some extent. The uplink receiver will always be switched on.

The transponder incorporates a gain controlled IF amplifier circuit to limit the transponder's dynamic range. After that, the signal is combined with telemetry from the BPSK modulator and subsequently upconverted to the transmit frequency in the 145 MHz band. The driver and final amplifier are designed to produce 0.4W PEP at the antenna port.

E. Antenna Subsystem

For the antenna subsystem the main goal was to achieve a near-omnidirectional pattern because the satellite does not incorporate any active attitude control. The antenna system consists of quarter-wavelength whips, four for the VHF downlink and four for the UHF uplink. A phasing network is incorporated to achieve the desired pattern.

The antenna subsystem has been analyzed using Numerical Electromagnetics Code (NEC). A test model has been made to verify the NEC results.

F. Thermal Subsystem

The satellite will be covered by Multi-Layer Insulation (MLI), which will have a black coating to prevent reflection of incident solar radiation against the back side of the Thin Film Solar Cell payload. The passive thermal subsystem has to cope with a relatively large internal dissipation compared to the satellite's volume. The amount of power that is to be dissipated is mainly dictated by the efficiency of the communications system power amplifier. The top and bottom panels of the satellite act as thermal radiators.

G. Attitude Determination and Control Subsystem

The satellite will not have active attitude control because this is not required to fulfill

the primary mission objectives. In fact, a slow tumbling motion is required since it allows all four TFSC panels to be exposed to solar radiation. However, a limit is posed on the satellite's rotation rates to obtain reliable test results for the TFSC payload. Therefore, rotation rate limiting using magnetic hysteresis materials is applied.

The attitude determination subsystem uses the supplied current and voltage from each individual GaAs solar panel to determine the sun vector with respect to the satellite's reference frame. Four side mounted Si solar cells are used as an extra reference for the attitude reconstruction algorithm. When the sun is within the 90 degrees square field of view of one of the two Autonomous Wireless Sun Sensor (AWSS) payloads, the reconstructed attitude data is augmented with the high accuracy data generated by the AWSS. The AWSS payload will be discussed in section IIIB.

III. PAYLOAD OVERVIEW

A. Thin Film Solar Cells

The Thin Film Solar Cell payload is based on the latest development in the area of photovoltaic cells by the Dutch space company Dutch Space. The cells consist of a CIGS photovoltaic layer that is deposited by evaporation on a titanium base layer of 25 micrometers. The cells will be integrated tile-wise ensuring a minimal loss of active cell area. The interconnects are covered by the next cell, with an overlap of 5 mm at the longest side. This mechanical interconnection has a low resistance ($\sim 1\text{m}\Omega$). It is placed between the gilded contact pads under low compressive pressure.

The aim of this new type of solar cell is to create a lightweight and low-cost product for future space applications. The target is a 50% cost reduction of solar arrays while improving the power to mass performance ratio by 50% compared to conventional solar cells. Cost is projected to be lower than 350 Euro per watt at solar array level and the power is expected to be more than 100 watts per kilogram. The cell will have

no need for a cover glass, but it will have an emissivity enhancing and encapsulating dielectric coating. The efficiency will be more than 12% under AM0 light conditions. The performance of the TFSC payload will be tested by determining their characteristic IV-curves and cell temperature per TFSC panel, which consists of two cells. The IV-curves will be measured by means of a programmable current sink; the temperatures will be measured by determining the electrical resistance of a dummy titanium cell mounted close to the actual TFSC's. This measured data is then transferred to the OBC where it is formatted for transmission to the ground station.

B. Autonomous Wireless Sun Sensor (AWSS)

Delfi-C3 houses two analog sun sensors located on opposite sides of the satellite that will be fully autonomous and wireless. With the typical internal volume of a nanosatellite already being quite limited, reducing wiring is an important challenge. The sensors will have a half-sized GaAs solar cell as their own power supply (Figure 6) making them

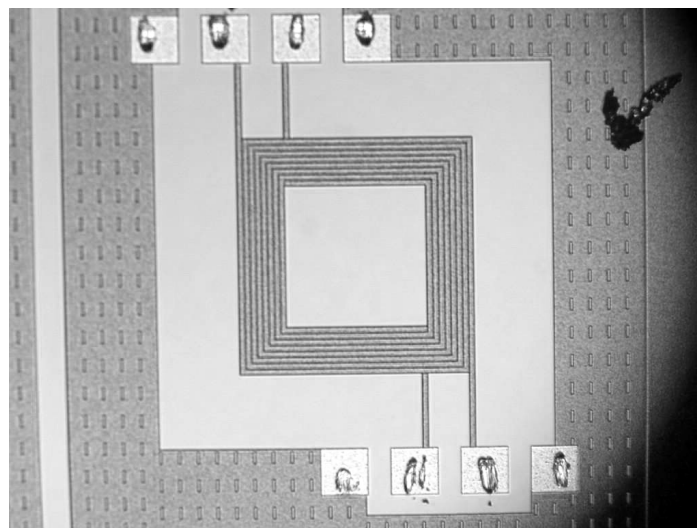


Figure 11: Integrated transformer.

independent of the satellite's electrical power system. This autonomy is accompanied by a radio frequency link. This link will be either an adapted commercial off-the-shelf transceiver or a custom designed ultra-wide-band connection, depending on data rates and technology readiness.

Although wireless data communication on board such small satellites might seem a bit superfluous in itself, implementing this technology adds to modularity and results in a flexible "plug-in and play" system. The autonomous sensor unit, in this case



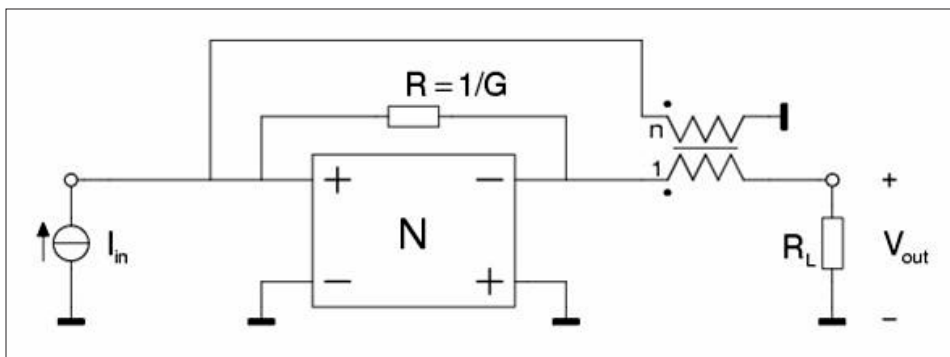


Figure 10: Double loop negative feedback using a transformer.

measuring approximately 60x40x20 mm, is a predecessor of an even smaller digital version that can be mounted on a solar panel sacrificing just a single solar cell.

The in-orbit experiment will concentrate on

IM3	0.9GHz	2.0GHz
FB	-46dBc	-43dBc
No FB	-29dBc	-33dBc

Table 1: IM3 improvement.

demonstrating the feasibility of the radio link (immunity to disturbances; no interference with other equipment) and the operation of the sun sensor under variable power supply conditions.

C. High Efficiency Advanced Transceiver

The MISAT mission [3], [4] aims at the development of microsystem technology for a cluster of small satellites. For each of these satellites one transceiver should be able to accommodate all radio communications. A crucial part in this is the availability of a wide-band, highly efficient and very linear PA. In this mission a PA will be tested that utilizes overall double loop negative feedback using integrated transformers in the feedback network and in the frequency compensation network. It has been shown that integrated transformers work very well in a wide band when used as feedback element [5]. Since negative feedback is a very powerful means to linearize an amplifier, the more nonlinearity of the active part, especially the power stage, can be tolerated. When more nonlinearity can be tolerated, it is possible to increase the efficiency of the power stage. Several experiments have shown that both a higher efficiency and a higher linearity can be obtained using this technique. Space qualification of this technique, where integrated transformers are optimized for wide-band use in feedback amplifiers, is crucial. The circuit diagram is shown in

Figure 10. Table 1 shows the improvement that has been achieved in a first experiment comparing amplifiers in the GHz range with identical active parts (and efficiency), one with and one without feedback.

IV. GROUND SEGMENT

The ground segment consists of three parts, the distributed ground station network, formed by Amateur Radio operators, a worldwide university ground station network and the Delfi command ground station at Delft University of Technology.

Distributed Ground Station Network

Delfi-C3 will transmit its telemetry data in plain AX.25 UI frames. Telemetry decoding software will be made freely available to participating radio amateurs so that they can decode and process the telemetry data locally. This data can then be uploaded to the centralized Delfi command ground station via an Internet connection for further analysis. The team is looking for amateur operators willing to participate in the data collection process.

Worldwide University Ground Station Network

In discussions with other universities involved in satellite development it became clear that sharing ground station resources worldwide would be very beneficial. At the moment, such a network is taking shape. At the time of writing, the following universities are participating in this network:

- Julius-Maximilians University Würzburg
- Aalborg University
- Brno University of Technology
- University of Bologna, Italy
- Fachhochschule Aachen, Germany
- Delft University of Technology, The Netherlands

The final objective of the network should be to create nearly worldwide coverage and hence the Delfi-C3 team would like

to invite universities around the world to participate.

Delfi Command Ground Station

The Delfi command ground station will act as the command ground station. This ground station is already operational and it provides valuable experience in satellite communication.

V. PROJECT PARTNERS

A. Dutch Space

Dutch Space (formerly Fokker Space) is a space company based in Leiden, The Netherlands. Dutch Space specializes in three areas of space technology: solar arrays, structures and mechanical systems and advanced systems and engineering.

B. TNO Science & Industry

TNO Science & Industry is the Dutch governmental scientific research institute specializing in the development of complete instruments or instrument subsystems for Earth observation and science space projects. Other competences include precision engineering and mechanisms, calibration key-data and attitude sensors for satellites.

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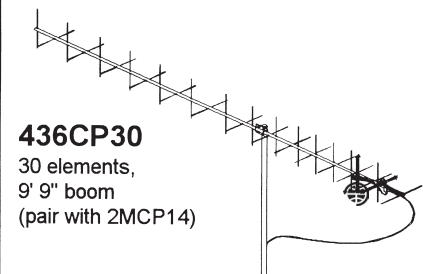
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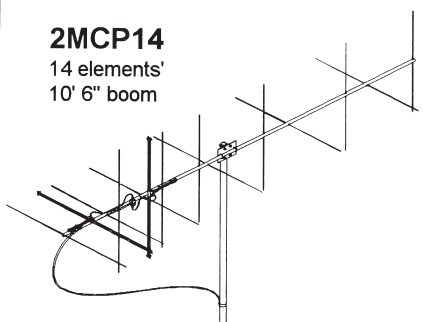
436CP42-U/G

42 elements,
18' 10" tapered boom
(pair with 2MCP22)



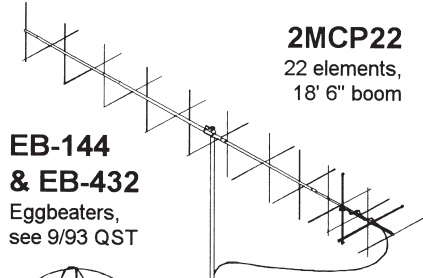
436CP30

30 elements,
9' 9" boom
(pair with 2MCP14)



2MCP14

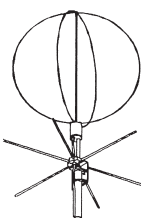
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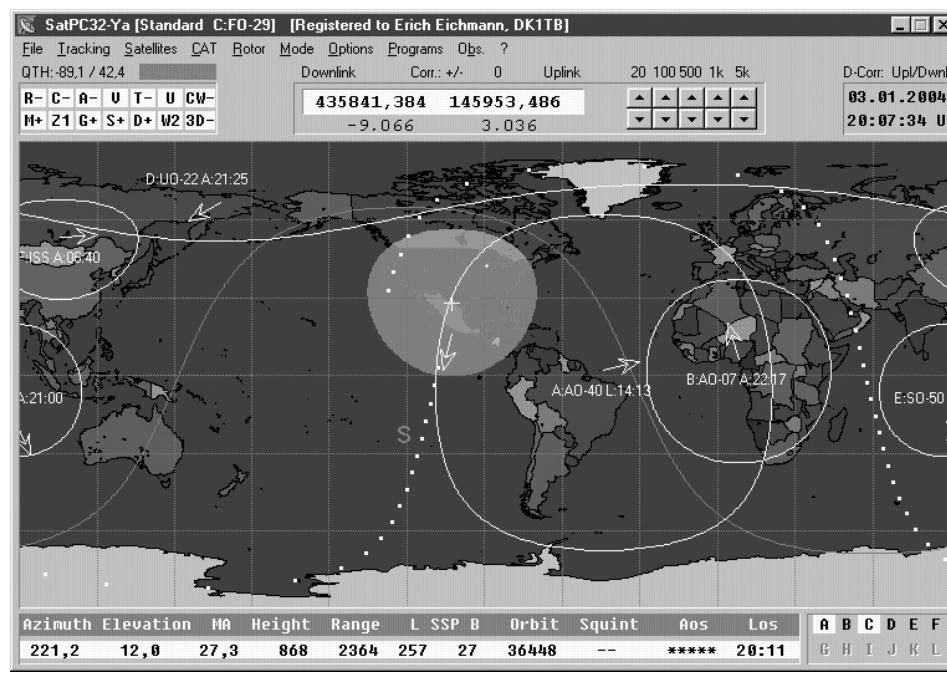
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EaglePedia

by Gould Smith, WA4SXM, wa4sxm@amsat.org

June 10, 2006

Today, Eagle Project Manager Jim Sanford, WB4GCS, announced that EaglePedia is now open for general use. EaglePedia is the communication medium used by the Eagle developers, and is now accessible to all AMSAT members. A basic principle of the Eagle project is open design, so Jim made the decision to open access to the Eagle development effort once EaglePedia, a new effort itself, was judged to be ready for general use. "The entire Eagle team has been enthusiastically supportive of openness to the members," said Jim. "We are excited to give all AMSAT members the opportunity to understand and to follow the design process of the various satellite components and system".

Emily Clarke, N1DID, has developed and customized the EaglePedia application using the MediaWiki software engine that was developed for Wikipedia. "I'd like to thank Emily for all her efforts. She has adapted the wiki product to our needs, educated the illiterati (mostly me) and added functions to make it easier for us to use. EaglePedia would not be the tool that it is, without tremendous effort on Emily's part, and I am extremely grateful for all her work."

All major decisions about the spacecraft and their supporting documentation will be

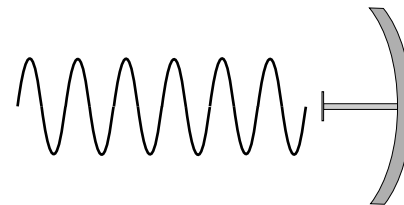
available through the site. Although only Eagle team members will have the ability to comment on what is posted there, all will be able to see them.

Jim notes that, "There will be some areas of the site that are available only for internal Eagle team communications during the preliminary development stages. I have made this decision to allow unfettered communications among the team during the early phases of concept refinement and design. Once peer review of a design is complete, the initial design, peer review comments, the resolution of those comments, and the revised and approved designs will all be available to AMSAT members."

Jim, the entire Eagle team and AMSAT President Rick Hambly encourage everyone interested in amateur satellites to take advantage of this 'new way of working' and to follow the Eagle design process and developments. "We are excited about offering the unprecedented access into Eagle's development. I fully expect this approach to enhance the Eagle design process and improve overall product quality," said Rick.

EaglePedia can be accessed via the AMSAT.org front page using the Eagle link in the 'Quick Access to Project Pages:' section found on the top right of the page.

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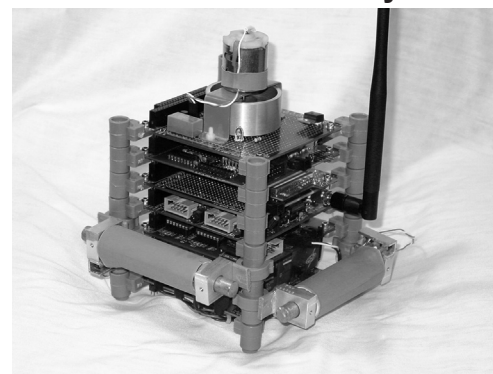
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WA4SWJ photo



Rick Hambly and Bob McGwier pose while wearing their new Eagle logo shirts at the Dayton Hamvention satellite demonstration tent outside the arena. You can get your Eagle shirt at amsat.org Web store. They are bright red with a yellow Eagle line logo as shown above the articles appearing in this issue on pages 24 and 25.

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AMSAT at the Amber Rose



N4HY Photo

Above: Mike Kalter, W8CI, President of the Dayton Amateur Radio Association (DARA), announces a gift of \$5000 to AMSAT from DARA. The gift was met with a standing ovation from the AMSAT members in attendance.

K3IO Photo

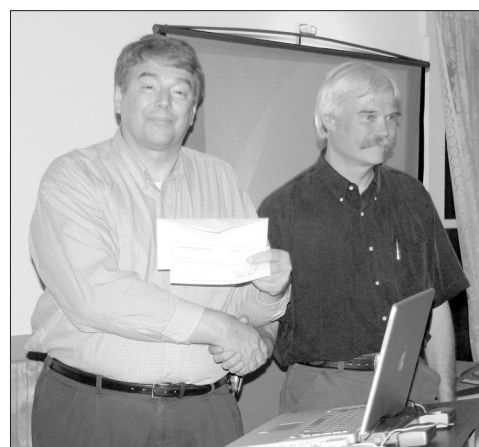


The crowd at the Amber Rose waits for dinner to be served. If you missed the banquet you missed a good time with the AMSAT team.



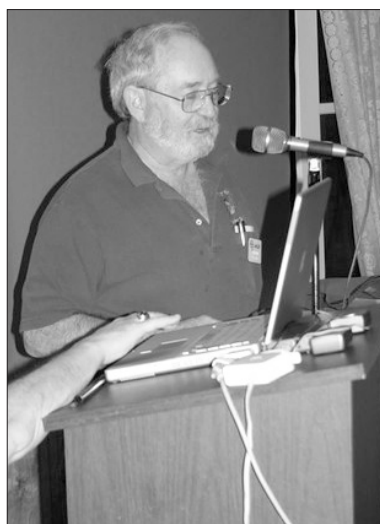
K3IO Photo

"Is a Fred in the room?" asked Rick Hambly, W2GPS, AMSAT President, during his presentation to the Annual AMSAT Banquet at the Dayton Hamvention. Christine "Fred" Crawford, KC8DGL, is 11 years old. She recently earned her technician license. Fred is a new AMSAT member and is also our youngest member. In this photo Rick presents "Fred" with her AMSAT membership certificate. Spread the word to answer her when she calls on AO-51 or other satellites.



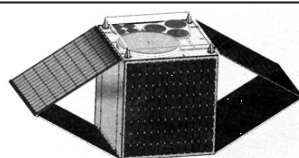
N4HY Photo

Left: Rick Hambly, W2GPS, AMSAT President, receives a check for \$5000 from Mike Kalter, W8CI, President of DARA.



N4HY Photo

Lou McFadin, W5DID, speaks to the Amber Rose crowd about a new power supply approach for satellites that uses very high value capacitors - in the thousands of farad range. The technology was demonstrated at the AMSAT booth during Hamvention.



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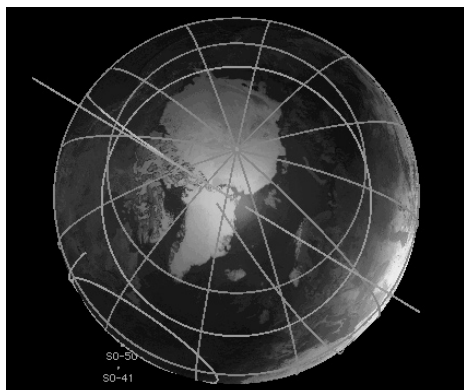
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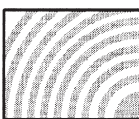
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Real World Helix Antenna Comparison Measurements

By Clare Fowler, VE3NPC, ve3npc@amsat.org

Abstract

Field test range comparative gain measurements were made on a number of helical antennas using the Kraus and Emerson design algorithms. The test results indicate helix antennas can be constructed with up to 52 turns (11.53 wavelengths long) that provide useful gain. Those constructed with circumferences greater than one wavelength using the Emerson design did not provide the predicted increase in gain over one constructed with a circumference of one wavelength and in one case had 6 dB less gain. The use of aluminum or PVC tubing for a boom did not significantly affect the gain or beam width.

Background

My experience with helix antennas first began when I got on satellite to work AO-10. I made 70 cm helix antennas using bamboo poles for booms. I then graduated to using fiber glassed 1 x 2 inch pine, but as time went on, I settled on using four-foot long fiberglass stakes. I constructed and made a number of 10-turn 70 cm helix antennas and combined them in 2 and 4 helix arrays. I developed the VE3NPC quarter wave match. [1]

When Oscar 13 was launched and mode S was activated, I procured and assembled a Down East Microwave down converter and a preamplifier kit. I then went through a number of attempts at constructing 12.5 cm helix antennas of various lengths and circumferences, all of which failed miserably in that I never even heard the beacon. I then constructed a four-foot dish and magically had an S8 signal, paralleling the experience of K5OE. Then later, when AO-40 provided mode L operation, I successfully constructed

a 23 cm array consisting of 4 x 27 turn helix antennas [2]. With the experience gained on 23 cm, I returned to work on a 12.5 cm array for use as a portable 2.4 GHz antenna for Field Day and hamfest demonstrations. The result was an array of 4 x 53 turn helix antennas, which subjectively appeared to provide a signal to noise ratio not as good as my four foot dish but better than what was being obtained by those using the popular "barbeque" antenna. Using the 23 cm and 12.5 cm arrays to work only AO-40 on mode L/S I made 102 QSO's to place 7th for Field Day 2003 [3].

Radio amateur publications have included different designs for helical antennas. The original design formula was developed by Kraus. Subsequently, Emerson, Cebik, Atkins and others have published design formula to provide peak gain [4,5,6]. The peak gain was achieved by tailoring the circumference and pitch angle relative to the number of turns. *The Satellite Experimenters Handbook* follows the Kraus design where the circumference is one wavelength and the pitch angle is 12.5 degrees.

Cebik and Emerson publish graphs plotting gain verses circumference (or radius) that show that maximum gain occurs with circumferences greater than one wavelength. While the gains are not identical between the designs, they indicate that the peak of this maximum gain, which occurs at some point where the circumference is greater than one wavelength, can be up to 3 dB greater than the gain indicated at the point where the circumference is one wavelength. This is not an insignificant amount. This implies that a helix antenna designed for peak gain would, in some cases, only need to be half the

length of one designed with a circumference of one wavelength to give the same gain. The Kraus design gain is several dB higher than that predicted by the peak gain design. *The Satellite Experimenters Handbook* however suggests the Kraus theoretical gain is 1 to 2 dB high. An amateur in reviewing these published designs would therefore normally elect to construct an antenna for satellite communication following a peak gain design.

The simple Kraus design gives a linear relationship between gain and antenna length. The peak gain designs indicate decreasing gain for increased antenna length. Emerson limits antenna length to 7 wavelengths. The Atkins design goes to 35 turns while Cebik provides data for antennas with up to 15 turns.

After constructing and using helix antennas for many years for amateur satellite communication, I found that my results did not correlate with the peak gain designs. They did not provide the expected greater gain and so I utilized the simple Kraus design. This state of events would have continued but for a discussion with David Conn, VE3KL. David, who writes articles for *The Canadian Amateur* on "Antennas & Transmission Lines", had indicated an interest in constructing a 70 cm helical antenna to monitor AO-51. He indicated he would make it similar to mine but follow the Emerson design. I informed him that, in my experience, this design offered little, if any benefit, over the Kraus design. Dave of course was skeptical. I suggested that after he had his antenna completed, we do an A/B comparison test. I had a weak signal source, a 70 cm to 10 m downconverter and a 10 m non-calibrated RF voltmeter that I had made to facilitate optimizing antennas and antenna arrays. It took several afternoons of field measurements to iron out discrepancies and to refine our measurements.

Partly due to the results of this comparison and further discussions regarding the 4 x 27 turn 23 cm helix array and the 4 x 53 turn 12.5 cm helix array I had constructed, both of which worked very well in satellite operation, Dave urged me to make further measurements and publish the results. Making fairly accurate repeatable measurements with very limited and mostly home built test equipment to compare antenna gains and radiation patterns

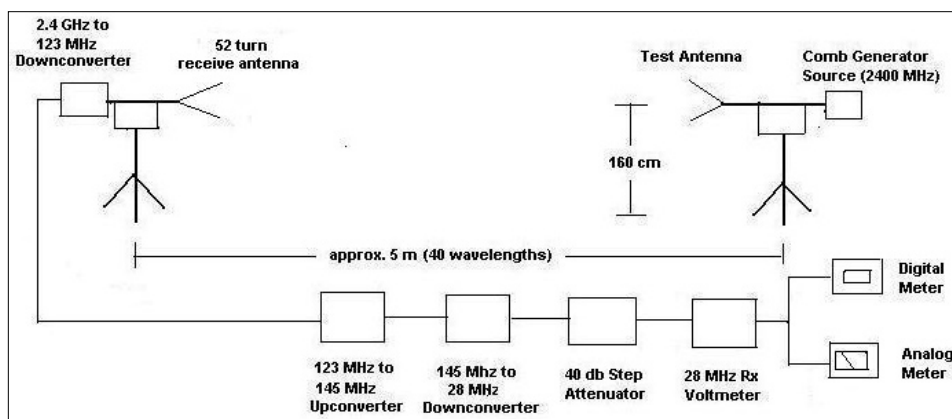


Figure 1: 2.4 GHz helix antenna comparison test range measurement equipment block diagram.



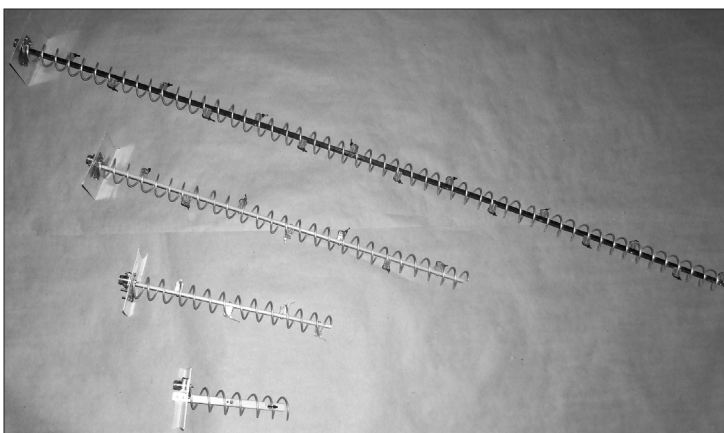


Photo 1: Four Kraus design helix antennas. Top to bottom: 11.53 wavelengths long, 5.76 wavelengths long, 2.88 wavelengths long and 1.44 wavelengths long.

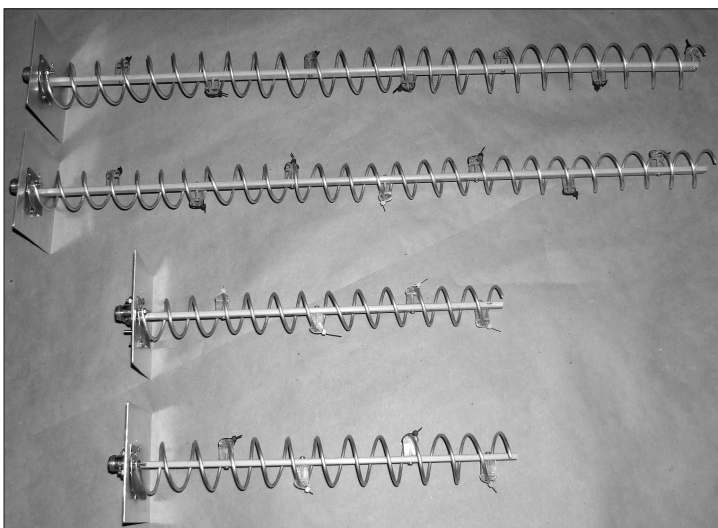


Photo 2: Helix Antennas. Top to bottom: Emerson design, 5.76 wavelengths long; Kraus design, 5.76 wavelengths long; Kraus design, 2.88 wavelengths long; Emerson design, 2.88 wavelengths long.

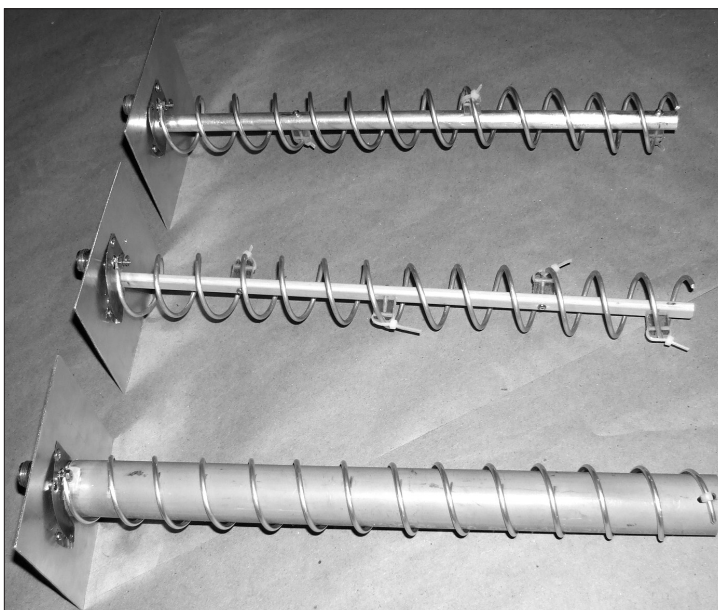


Photo 3: Kraus design 2.88 wavelength long helix antennas. Top to bottom: 1/2" aluminum pipe boom, 13 mm x 5 mm fiber glass boom and 25 mm PVC conduit pipe boom.

of even similar antennas, turned out to be a much greater challenge than I had anticipated.

Objectives

The primary objective was to test the validity of the different designs relative to:

The difference in gain relative to the number of turns (length in wavelengths).

- Peak gain design verses the simple Kraus design.

A secondary objective was to determine:

- The effects of using PVC or aluminum for a boom.

Determination of the absolute gain of the antennas was not an objective.

Meeting the Objectives

To meet these objectives 10 different helical antennas were constructed and assigned numbers for purposes of identification.

The antenna identification numbers are:

- 1A 10 turns (2.22 wavelengths), Kraus design
- 2A 10 turns (2.40 wavelengths,) Emerson design
- 1 6 1/2 turns (1.44 wavelengths), Kraus design
- 2 13 turns (2.88 wavelengths) Kraus design
- 3 26 turns (5.76 wavelengths), Kraus design
- 4 52 turns (11.53 wavelengths), Kraus design
- 5 12 turns (2.88 wavelengths), Emerson design
- 6 24 turns (5.76 wavelengths), Emerson design
- 7 13 turns (2.88 wavelengths), 25 mm PVC conduit boom, Kraus design
- 8 13 turns (2.88 wavelengths), 1/2 inch aluminum pipe boom, Kraus design

Antenna numbers 1A and 2A were 70 cm antennas with the following common parameters:

- Center frequency – 436 MHz
- Conductor – 3 mm diameter aluminum wire
- Reflector – 42 cm x 42 cm (0.6 wavelengths) 1/2" hardware cloth
- Match – quarter wave ground plane (VE3NPC design)
- Boom – 13 mm x 5 mm rectangular x 5 ft long fiberglass stake

Antenna numbers 1 to 8 were 12.5 cm antennas with the following common parameters:

- Center frequency - 2401 MHz
- Conductor – 3 mm diameter aluminum wire
- Reflector – 10.5 cm x 10.5 cm (0.84 wavelengths) aluminum
- Match – quarter wave ground plain, (VE3NPC design)
- Boom – 13 mm x 5 mm fiberglass (except for ants 7 & 8)

Objective 1 can be met by comparing antennas 1, 2, 3 and 4. If as Kraus indicates, the gain is linear with increasing wavelength length, the incremental theoretical gain differences relative to antenna number 1 should be 0, +3dB, +6dB, and +9dB as the antenna length doubles in each case.

Objective 2 can be met by comparing antenna 1A to antenna 2A, and antenna 2 to antenna 5, and antenna 3 to antenna 6. If the Emerson design holds, the gain over a Kraus with a 1-wavelength circumference, should be up to +3dB greater.





Photo 4: Emerson design 5.76 wavelength long helix antenna and 2400 MHz signal source in fiberglass cradle.



Photo 5: 2.4 GHz helix antenna test range. The receiving voltmeter system is on the table and the 2.4 GHz downconverter and receiving antenna on the tripod are on the left. The antenna under test and the signal source are on the tripod in the center. Two gel cell batteries supply power. The spacing between the tripods has been reduced to take the picture.

Objective 3 can be met by comparing antenna 2 to antennas 7 and 8. If the PVC or aluminum boom have an effect on the design the gain and beam width should differ.

Measurement Method

Figure 1 shows the test range equipment set up block diagram for the 12.5 cm helix antenna comparison measurements.

A sensitive RF voltage measuring system was assembled. It consisted of a high gain antenna feeding a low noise, high gain 2.4

GHz to 123 MHz down converter connected via a coaxial feed line to a 123 MHz to 145 MHz up converter. The 145 MHz up converter output was then down converted to 28 MHz. The 28 MHz signal was connected through a 40 dB step attenuator to a receiver with no AGC and manually adjustable gain. Amplified DC voltages from the receiver detector were fed to both an analog and a digital voltmeter. A 24 MHz comb generator was used to provide a 2400 MHz weak signal

to excite the antenna under test.

With the reference antenna as the antenna under test the step attenuator was set in the 30 to 35 dB range and the receiver manual gain control set for a reference digital voltmeter reading (nominally 470 mV). The analog meter was used for peaking the frequency tuning.

To determine the gain of another antenna relative to the reference antenna it was substituted for the reference antenna. Attenuation was either added or removed with the step attenuator to return the reference meter reading to the initial reference point within 1 dB. Interpolation between the 1 dB steps was made using the digital voltmeter where approximately 5 mV = 0.1 dB.

To measure the beam width of an antenna the attenuation was reduced by 3 dB from the reference setting. The antenna was then rotated until the reading returned to the initial reference reading and the number of degrees of rotation as indicated on the azimuth scale was noted. The antenna was rotated both in the clockwise and counter clockwise directions to confirm symmetry and absence of reflections.

To measure the azimuth radiation pattern the same procedure used for determining the 3 dB beam width was followed with the attenuator adjusted for the reference reading at every 5 degrees. Peak and null degree points were also noted and measured.

Measurement Results

The antenna comparison results are given in Tables I, II and III.

The “theoretical gain” and the “theoretical beam width” are as derived by the Kraus or Emerson formulas as applicable.

The theoretical gain of the Kraus design with a circumference of one wavelength and a pitch angle of 12.5 degrees is:

$$G(\text{dB}) = 10 \log 3.325 n$$

where n is the number of turns.

The theoretical G_{max} gain of the Emerson design is:

$$G_{\text{max}}(\text{dB}) = 10.25 + 1.22 L - 0.0726 L^2$$

where L is the length in wavelengths.

It is also important to note the difference between forward gain and directivity. An antenna may be very directive, i.e., exhibit a narrow forward beam width but due to the configuration of the side lobes and/or degree of losses, provide higher or lower forward gain.





Antenna polar plot patterns are shown in figures 2 to 9. All rear pattern measurements were down more than 25 dB but are not plotted, as they are not considered to be sufficiently accurate due to the source signal starting to drop into the noise and the probability of the presence of reflections.

Objective 1 Results. Refer to Table I

The “incremental measured gain” between antennas 1, 2 and 3 is very close to the “incremental theoretical gain”. This validates the linear relationship between gain and antenna length in wavelengths for antennas up to at least 6.5 wavelengths long (30 turns) for the Kraus design, where the circumference equals one wavelength and the pitch angle equals 12.5 degrees. The “measured beam width” of antennas 1, 2 and 3 was also in close agreement with the “theoretical beam width”. However the incremental gain of antenna 4 over antenna 3 is only half the theoretical value and the beam width is narrower than the theoretical. This suggests the effects of losses and or increased number of side lobes although they were all greater than 20 dB down.

The “incremental measured gain” relative to antenna length for the four Kraus design antennas is plotted in Figure 10.

The polar patterns (see Figures 4, 5, 6 and 7) all show side lobes to be 11 dB or more down.

Objective 2 Results. Refer to Table II

The “theoretical gain” of Kraus design antennas and Emerson design antennas are not directly comparable as they are calculated differently as noted above. The actual gain is not the issue under discussion however.

The “measured relative gain” results between Kraus helix antennas with a circumference of 1 wavelength and Emerson with circumferences greater than 1 wavelength did not provide the predicted increase in gain. The 70 cm Emerson 2.40 wavelength long antenna had only about 1 dB “measured relative gain” over the 2.22 wavelength long Kraus antenna. But the Emerson shows a narrower “measured beam width” and more side lobes. See Figures 2 and 3. The 12.5 cm Kraus and Emerson 2.88 wavelength long antennas had nearly equal “measured relative gains” but the Emerson polar patterns again show a narrower beam width and increased side lobes over the equivalent Kraus. See Figures 5 and 8.

The measurements of the Emerson 5.88

Antenna Number	Number of Turns	Length in Wavelengths	Kraus Theoretical Gain (dB)	Incremental Theoretical Gain (dB)	Incremental Measured Gain (dB)	Theoretical Beam Width (degrees)	Measured Beam Width (degrees)
1	6-1/2	1.44	13.4	0	0	43.3	46
2	13	2.88	16.4	+3.0	+2.9	30.6	32
3	26	5.76	19.4	+6.0	+6.2	21.7	20
4	52	11.53	22.4	+9.0	+7.5	15.3	12

Table I: Measurement comparison results between four Kraus design helix antennas of increasing length where the circumference is one wavelength and the pitch angle is 12.5 degrees.

Antenna Number and Design Type	Number of Turns	Length in Wavelengths	Theoretical Gain (dB)	Measured Relative Gain (dB)	Theoretical Beam Width (degrees)	Measured Beam Width (degrees)
1A Kraus	10	2.22	15.2	0	34.7	40
2A Emerson	10	2.40	12.8	+1	29	36
2 Kraus	13	2.88	16.4	0	30.6	32
5 Emerson	12	2.88	13.2	+0.4	27	25
3 Kraus	26	5.76	19.4	0	21.7	20
6 Emerson	24	5.76	14.9	-6.1	20	44

Table II: Comparison measurement results between Kraus design and Emerson design helix antennas. The theoretical gain and beam width are the values derived by the respective Kraus and Emerson design formulas.

Antenna Number and Boom Material	Number of Turns	Length in Wavelengths	Kraus Theoretical Gain (dB)	Measured Gain Relative to Antenna #2 (dB)	Theoretical Beam Width (degrees)	Measured Beam Width (degrees)
2 Fiberglass	13	2.88	16.1	0	30.6	32
7 PVC Pipe	13	2.88	16.1	+0.3	30.6	30
8 Aluminum	13	2.88	16.1	0	30.6	32

Table III: Measurement comparison results between Kraus design helix antennas with different boom materials.

wavelengths long antenna, indicates a wide departure from the Emerson predictions. The “measured relative gain” is over 6 dB less than the Kraus design. The “measured beam width” is much wider with a dip on each side of center, and increased side lobes. See Figure 9.

Objective 3 Results. See Figures 6 and 9

The 2.88 wavelength long Kraus design helix antennas with the same pitch and circumference with different boom structures showed no or only very small differences in gain and beam width. The “measured relative

gain” and “measured beam width” of antenna number 8 with a ½ inch diameter aluminum boom are the same as those of antenna number 2 which has a ½” x 7/32” rectangular fiber glass boom. This result supports the claims that the use of a centered aluminum tube will not degrade performance. The “measured relative gain” of antenna 7 with the PVC pipe boom had slightly more gain than antenna number 2 with the fiberglass stake boom. The “measured beam width” was slightly narrower, which tends to indicate that the side lobes may be larger. As the difference is very small it does not





support the commonly held view that PVC should not be used, as it will significantly reduce performance.

Conclusions

1. It is possible to construct a helix antenna with up to 30 turns (6.5 wavelengths long) that will provide the predicted increase in gain. Realizable gain can be obtained from antennas up to 11 wavelengths long.
2. These findings cast serious doubt on the validity and usefulness of the peak gain designs. Further evaluation along with collaborating test site measurements need to be made.
3. The use of aluminum for boom material has no affect on performance and the use of PVC also has minimal affect (at least for antennas up to 3 wavelengths in length).

Appendix

Axial Ratio

The axial ratio was also checked on the Kraus antennas and was less than 0.5 dB.

Measurement Equipment

Weak signal source: 24 MHz comb generator - 50 ohm output into a type N connector, battery powered, enclosed in die cast metal box (home built).

RF voltmeter receiver system:

2400 MHz 52 turn helix receive antenna (home built).

2400 MHz to 123 MHz down converter (AIDC 3731AA).

123 MHz to 145 MHz up converter (home built).

145 MHz to 28 MHz down converter. (Hamtronics).

435 MHz to 28 MHz down converter. (Hamtronics).

535 MHz preamplifier (home built).

40 db step attenuator, 1 dB steps. (Kay).

Tunable 28-30 MHz receiver with manual gain (no AGC), digital and analog meter carrier level readout, bandwidth about 6 KHz (home built).

Directional Coupler - 2.4 GHz, directivity 20db (home built).

Fiberglass tubing test antenna support tripod with fiberglass stake cradle and hand rotating mast with one-degree azimuth disk chart.

Measurement Procedures

The SWR of the antennas under test was adjusted to be less than 1.5:1.

The SWR of the 70 cm helix antennas were measured with an AEA sweep analyzer. The SWR of the 12.5 cm antennas was adjusted with the weak signal source driving the directional coupler with the RF voltmeter system used for the detector.

For the early on measurements of the 70 cm antennas a dipole transmitting antenna was connected to the weak signal source. The test antennas were connected in turn to a 70 cm low noise preamp feeding a 70 cm to 10 m down converter. For the later 12.5 cm measurements the procedure was changed. The AIDC down converter of the RF voltmeter system was connected directly with a type N barrel connector to a high gain receiving antenna. A high gain antenna was used at the receiving end to provide a narrow beam width to reduce reflection interference. The weak signal source was connected with a type N barrel connector directly to the antenna under test.

Measurement Limitations

The 70cm antennas were measured outdoors in the fall. Due to the use of a low gain antenna at the signal source end, the height of the antennas above ground and the distance between the signal source and the receiving antenna under test, the measurements were influenced by the presence of ground reflections. However since it was an A to B comparison the same conditions exists for both antennas under test so the difference in forward gain should be fairly close. The polar plots and 3 dB beam width however may not be all that accurate.

Some 12.5 cm antennas were measured indoors in the winter in a fairly large church hall. As a result of the much shorter wave length at 12.5 cm reflections in the forward +/- 45 degrees in azimuth could not be detected by moving the antennas slightly closer or up or down. However most of the debugging and repeated check measurements were done in the confines of a small room and hallway in my home. Over a five-month period over 700 separate measurements were recorded and probably twice that many were made where no record was kept. The home and church hall measurements, while very useful, were inconsistent and questionable. Final gain and pattern comparison measurements were done outdoors in an unobstructed location when the weather permitted.

Measurement Problems

Initial measurement results were erratic and very questionable to say the least. Problems

resulted from the weak signal source output impedance not being 50 ohms, (modified the signal source); test antenna SWR being set by physical spacing measurement, (constructed directional coupler to measure and adjust the 50 ohm match); poor and loose coax cable connectors, (repaired or replaced); a 2 inch #8 metal machine screw used in the test antenna mounting cradle an inch below the antenna near the feed end was found to reduce the gain in one case by 3 dB, (replaced all the machine screws in the proximity of the test antennas with nylon types); loose nuts and machine screws on the test antennas, (tightened); some drifting of oscillators in the weak signal source and RF voltmeter system, (modifications made); use of 3 turn low gain antenna on the receiving end which resulted in poor rejection of reflections (constructed another 52 turn antenna); frequency instability in the RF voltmeter receiver due to a solder bridge in a mixer stage; insufficient voltage regulation; non linearity due to inadequate amplifier stage gain in the 123 MHz to 145 MHz up converter.

The problems were discovered, found and corrected by making many, many repeated measurements and much head scratching.

After the problems had been ascertained and corrected the measurement results reported are derived from sets of measurements made on three different days each at a different outdoor locale. However, gain comparison measurement accuracy is limited to about +/- 0.4 db due to system instabilities primarily related to temperature. Azimuth determination is limited to +/- 1 degree due to backlash and torque in the tripod. Nevertheless this is sufficiently accurate to realize the objectives.

Acknowledgement

To David Conn, VE3KL, for the impetus and encouragement and help in preparing this paper.

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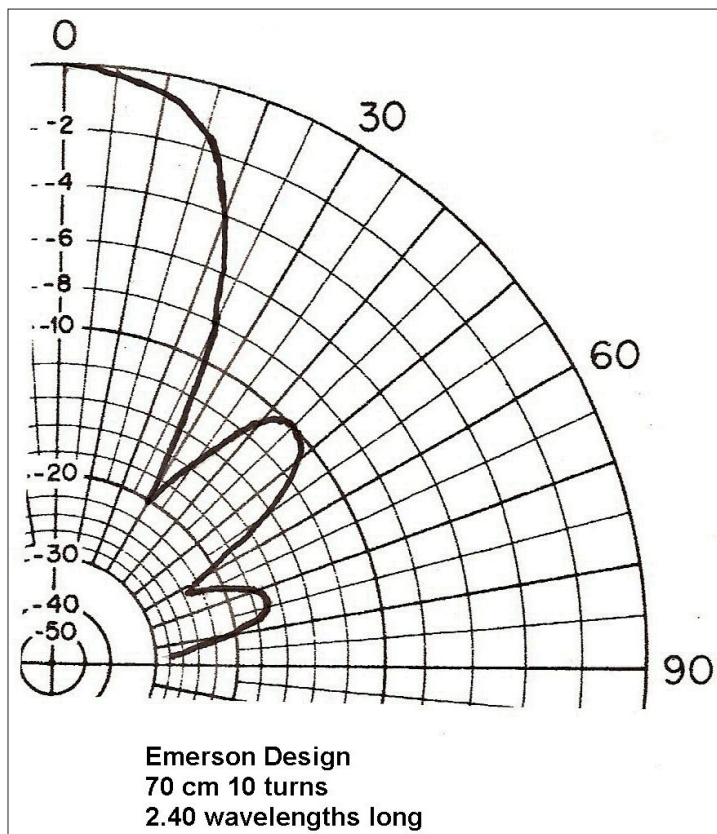


Figure 3: Directive pattern of antenna number 2A.

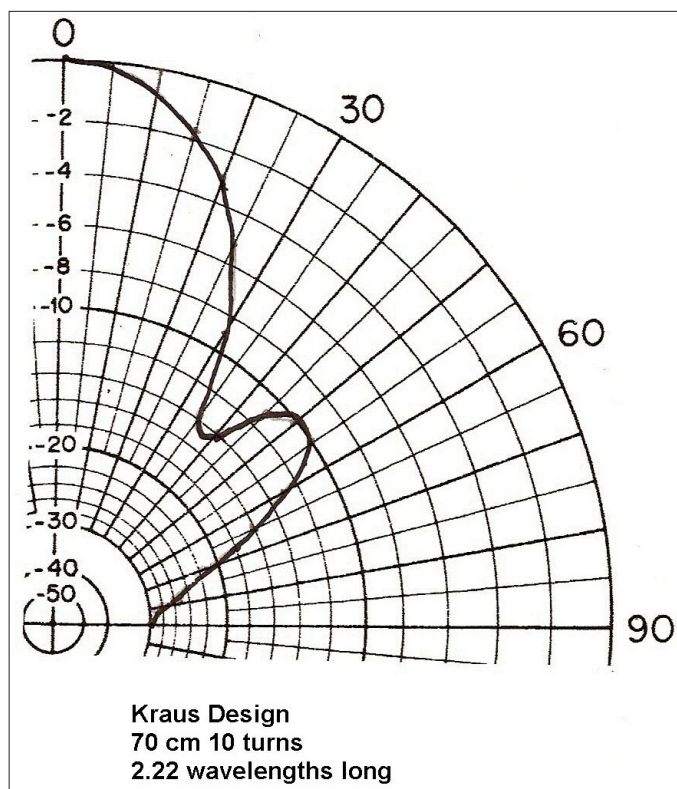


Figure 2: Directive pattern of antenna number 1A.

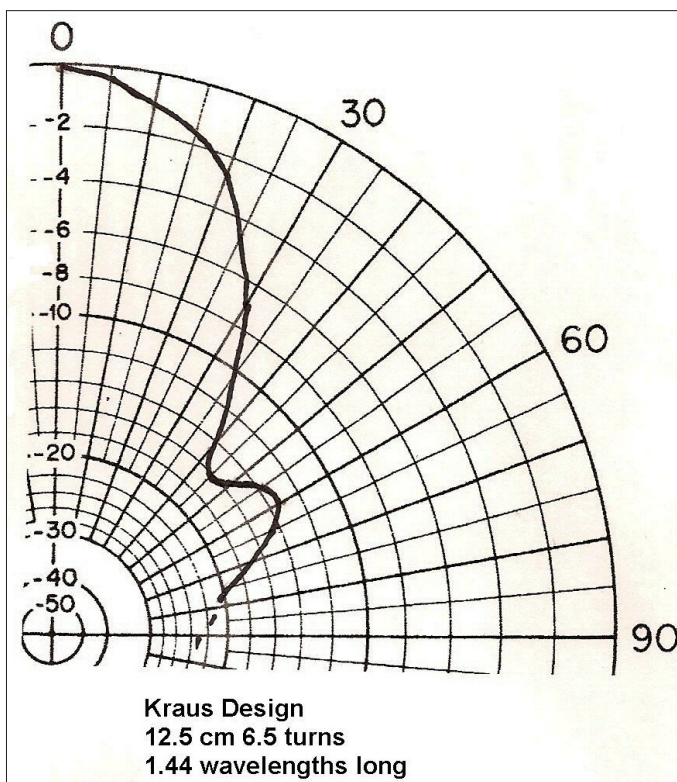


Figure 4: Directive pattern of antenna number 1.

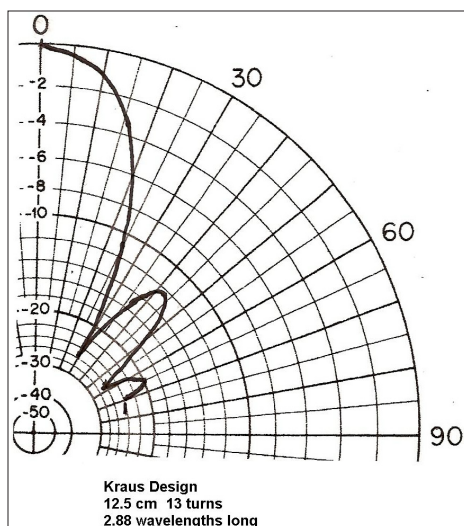


Figure 5: Directive pattern of antenna number 2.

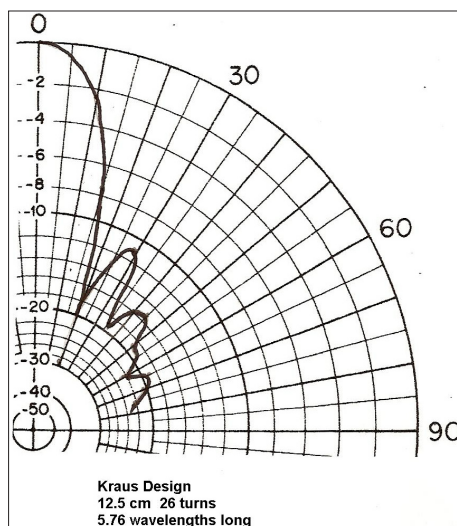


Figure 6: Directive pattern of antenna number 3.

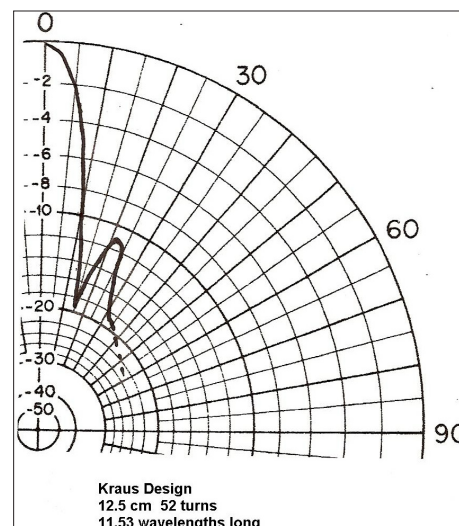


Figure 7: Directive pattern of antenna number 4.

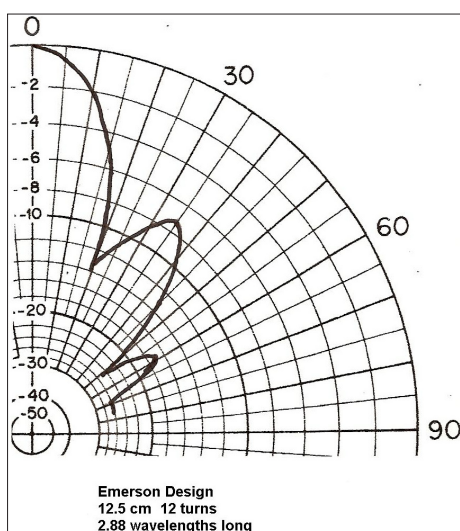


Figure 8: Directive pattern of antenna number 5.

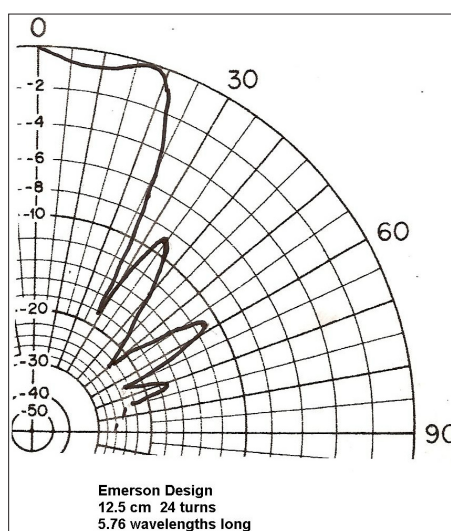


Figure 9: Directive pattern of antenna number 6.

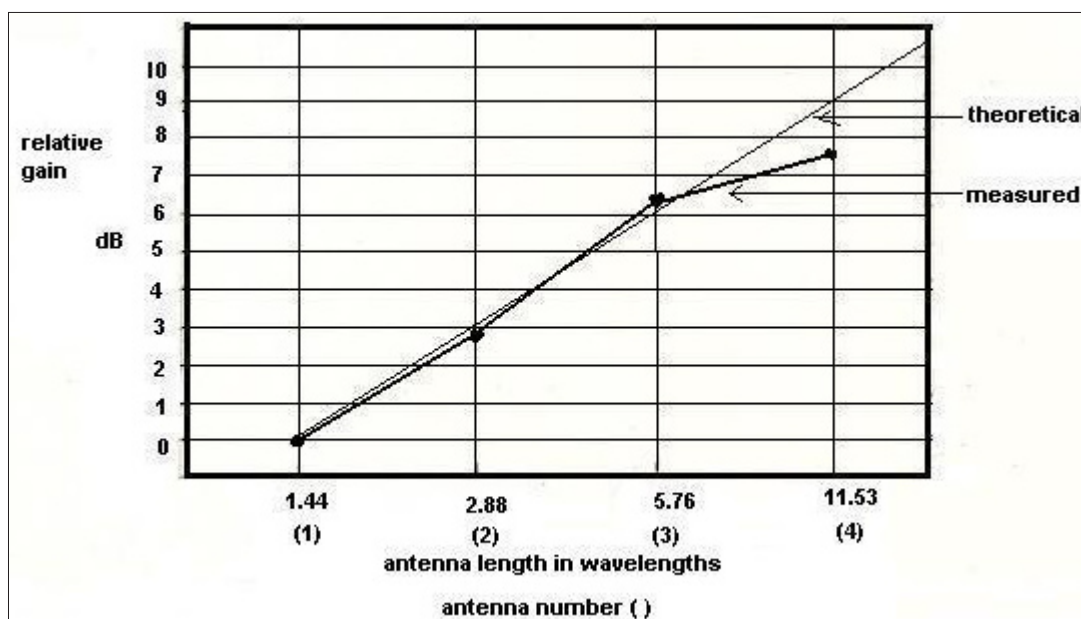


Figure 10: Measured gain differences between Kraus design antennas of 2.88, 5.76 and 11.53 wavelengths long relative to one that is 1.44 wavelengths long.



The Orbital Classroom - "Hams In Space!"

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AMSAT Director of Education



The Orbital Classroom

Remember the Muppets? From 1976 to 1981, these puppet creatures, created by the late Jim Henson, had their own TV variety show. One humorous recurring segment was the 'Pigs In Space!' science fiction spoof, starring Kermit the Frog's longtime romantic interest, Miss Piggy Lee (a porcine torch singer loosely based upon a popular, but slightly overweight, singer of the time with a similar name), and set aboard the *S.S. SwineTrek*. This Muppet sketch in turn inspired a popular "Hams In Space!" tee shirt, sold as an AMSAT fundraiser for a few years, and depicting radio amateur satellites in orbit, being operated by – well, hams. I still wear mine to hamfests.

Who, in fact, was the first actual ham in space? Legend has long held that Col. Yuri Gagarin, Hero of the Soviet Union and the first human to orbit the Earth, held Amateur Radio call sign UA1LO. I, in fact, inadvertently helped to disseminate this legend (the veracity of which is now in doubt), in a letter to an aviation journal[1]. It turns out that my claim, which has appeared widely in the Amateur Radio literature both before and since, resulted from an interesting misunderstanding.

At a time when radio contacts across the Iron Curtain were relatively scarce, Soviet QSL cards were here considered quite the prize. One, received in the mid 1960s by a US ham, documented a contact with UA1LO. It sported a photo of the famous cosmonaut,

and was signed "73, Yuri." Though Gagarin's tragic death in an airplane crash in March 1968 made the assumption impossible to verify, many of us accepted this QSL as proof that the first man in space had indeed been a ham.

Recent discussions on the amsat-bb email reflector have shed some light on what now appears to be a legend born of good intentions. Printed QSL cards, a costly commodity, were a luxury that most Soviet hams could ill afford. It was common practice to add one's call sign, by linoleum block printing, to purchased picture postcards, and to inscribe all relevant QSO information on the back. Tourist postcards of the day featured breathtaking natural landscapes, architectural masterpieces – and, of course, the faces of Heroes of the Soviet Union. A popular postcard featuring Gagarin's countenance was apparently used for this purpose. The fact that he and UA1LO shared the relatively common given name "Yuri" gave this appealing rumor life of its own. But, it now appears that the Yuri who operated UA1LO, and the first human in space, were not one and the same.

Gagarin notwithstanding, there is no controversy at all surrounding the identity of the first radio amateur to *operate from* space. That honor fell to Dr. Owen Garriott, W5LFL, aboard the Space Shuttle Columbia on its mission STS-9, in early December of 1983. Garriott had previously tried

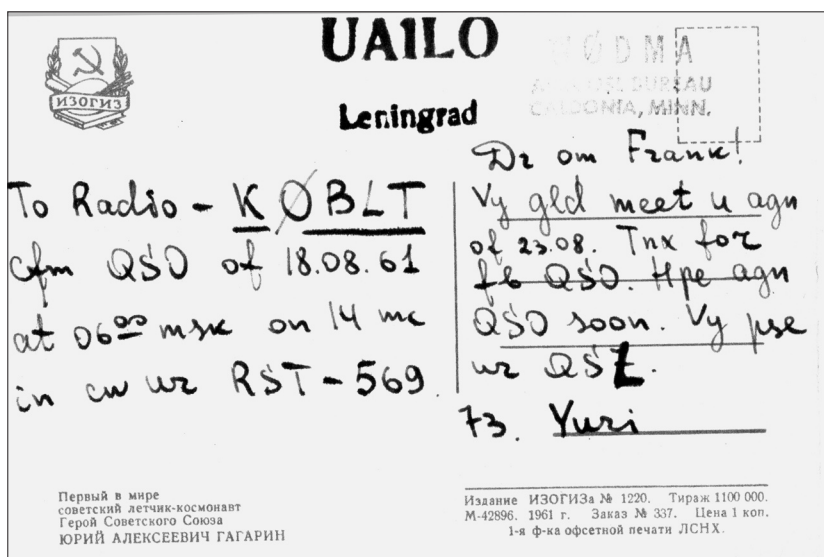
unsuccessfully to obtain authorization for ham radio activity aboard the Skylab space station, during its second manned mission a decade earlier. By the time STS-9 flew, small HT technology had made amateur operations from space far more feasible.

W5LFL's shuttle operations were far more than a space DXpedition. He justified the equipment to his NASA colleagues as a necessary backup communications system. But, as an electrical engineering professor at Stanford, Owen Garriott was interested in the educational opportunities his mission could afford, and worked hard (through both NASA and AMSAT) to involve schools in his historic flight. During the months preceding the STS-9 mission, secondary schools, colleges, and universities around the world clamored to complete stations for the sole purpose of contacting the first ham in space. Those that succeeded received not just QSL cards, but personalized, autographed photos of W5LFL operating his HT on-orbit (see photo).

Thus was born SAREX, the Shuttle Amateur Radio EXperiment, a joint NASA/AMSAT initiative to include amateur radio activity on as many subsequent Space Shuttle Missions as possible. Most astronauts hastened to earn their ham radio licenses. Many continued the proud tradition of conducting school contacts from space. Russian cosmonauts similarly installed ham radio equipment aboard their long-lived MIR space station,



"World first soviet pilot-cosmonaut Hero of Soviet Union Yuri Alexeyevich Gagarin"



IZOGIZ publication No 1220. Circulation 1,100,000 copies. M-42896. 1961 year. Order No 337. Price 1 kopeck. 1-st Offset Printing Factory of the LSNE" (acronym of the Leningrad Soviet of National Economy)



AMSAT Eagle Update

James A. Sanford, PE, WB4GCS, Eagle Project Manager

Our Vision is to deploy high earth orbit satellite systems that offer daily coverage by 2009 and continuous coverage by 2012...

and routinely contacted school groups, as well as ham club stations and individual amateurs, from low-Earth orbit. The SAREX and MIR traditions continue today, through ARISS (Amateur Radio on the International Space Station), involving a permanent ham station aboard the ISS, providing hundreds of opportunities for school groups around the world to talk to hams in space.

To most students, the holy grail of ARISS and its predecessors has been that coveted QSL card, along with the contact that enabled it. But, to their teachers and advisors, a ham contact with a manned spacecraft represents a unique educational opportunity. From radio communications to orbital mechanics to geography and language, ARISS contacts provide an impetus for the development of interdisciplinary curricula at all levels. It is my role, as AMSAT Director of Education, to help coordinate these efforts. If you are involved with an ARISS contact, as a teacher, parent, control operator, mentor, or advisor, I hope you'll register as an official AMSAT Educator (forms for that purpose are available on the AMSAT Web site).

Your mission (should you decide to accept it) is to make sure that the educational opportunities do not end with Loss of Signal. Hams In Space are here to stay. Let's exploit the attendant educational opportunities, to the max! 📡



W5LFL operating from orbit, December 1983.
The inscription on the photo reads "To Paul Shuch N6TX, and all the students, San Jose City College - from the spacecraft Columbia. 73 Owen W5LFL"

I write this one day after returning from a successful Dayton Hamvention. Rumor has it that attendance was up this year, and it certainly looked that way from where I sat and stood. AMSAT had many visitors and the AMSAT Forum was unprecedented in length. The Eagle team alone had an hour for presenting progress and prognosis. Thanks to Barry, WD4ASW, for arranging and moderating this session. During the forum, Bob, N4HY, made some remarks on our software defined transponders (SDX); Lyle, KK7P, provided updates on the IHU and CAN-Do! Widgets, which will be Eagle's brain and nervous system; and Howard, G6LVB, demonstrated an SDX that he has developed. Lou, W5DID, remarked on the energy storage and power conversion technologies we're considering for Eagle. Other topics during the AMSAT forum were P3E status by Rick, W2GPS, and a SuitSat briefing by Frank, KA3HDO.

The AMSAT booth had more space than usual this year. Some of the extra space was devoted to Eagle. We demonstrated a working SDX, making QSO's across the booth and out to the parking lot (more on this later). Professor Dr. Tom Clark, K3IO, was on hand to explain the workings and advantages of the SDX. Some standard payload module engineering models were on display as was a 2600 F UltraCapacitor. That's right, 2600 FARADS! Lou also demonstrated a 5F capacitor and power conversion board that was powering a weather radio for extended periods of time. We also displayed schematics of John Stephenson's, KD6OZH, 70cm receiver design.

As we demonstrated working hardware and software, I could sense a different conversation than we had a year ago. Rather than, "why don't you guys . . ." the discussions were more focused on how things we demonstrated work, and what they will mean to average users. This is exciting stuff.

As I was discussing with Bob and others the improved linearity that the SDX will offer compared to what we're used to, I realized how CLEAN the transponder sounded. I remember listening with difficulty to SSB on AO-40, no matter how loud. This transponder sounds natural and is easy to understand.

By the time you read this the U-band receiver design by John Stephenson, KD6OZH, will have completed the peer review process. I expect to authorize construction of a prototype in the next week or two and we expect to show you hardware and test results at Symposium in October.

Your Eagle team has been exploring various means to communicate and collaborate over distances – we now have tools at our disposal that simply did not exist during earlier satellite design. One meeting tool we're using is an Internet conferencing tool called TeamSpeak. At a meeting for Software Defined Radio aficionados, I was able to meet and personally thank Eric Ellison, AA4SW, who provides us this access at no charge. Formal discussions are held monthly and ad-hoc informal sessions among groups or individual teams occur when needed. This has been an invaluable tool for keeping Eagle moving without the expense of extensive travel.

Another tool we're using to both communicate and archive our work is EaglePedia. This is a *wiki*, similar to Wikipedia, but with some enhancements and configuration control. In keeping with Eagle's fundamental tenet of openness, we are now making this site, while still under construction, available to all members. [See the announcement elsewhere in this issue – Ed.] You can get to it from the AMSAT Web page and you will find a wealth of information there, ranging from how I think and am managing this project, to details of various designs. To be sure, *some* things will never be public – command and control issues, evolutionary design iterations, etc., must remain private. Team meeting reports, component designs once released to peer review, and various other analysis papers will be there. As the designs evolve, you'll be able to see the initial design, Peer Review comments and resolutions and the resultant final design. Eventually, you'll be able to read test plans and results. Once "construction" is complete, EaglePedia will continue to be a "work in progress," so check it often. Again, thanks to all of you who stopped by at Dayton.

As always, comments and questions to: wb4gcs@amsat.org
73,
Jim



Eagle Solar Panel Deployment Report

by Dick Jansson, WD4FAB, rjansson@cff.rr.com

Introduction

The Eagle satellite engineering team is attempting to design a spaceframe that will provide solar power generation at any solar attitude or Beta angle (β angle). This design feature provides useful power generation without a consideration of the orbital plane characteristics and antenna pointing angles of the final orbit giving wide latitude in selecting an obtainable orbit without the need to enforce operating “seasons” for the Amateur Radio transponder payload of the satellite. Such seasons in past satellites were caused by the satellite orbit geometry resulting in insufficient illumination from the solar power generator during semi-periodic seasons. Eagle is being designed to circumvent those issues and to provide full annual operating time for the payloads limited only by the antenna properties themselves.

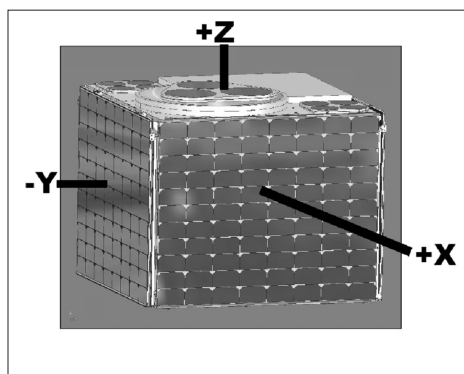


Figure 1: Eagle solar panels closed for launch. Spacecraft axes are shown with the Z spin axis through the top, the X panels facing and -Y panels left.

This discussion will reference the coordinate system for Eagle with the spin axis about the antennas mounted on the +Z side and with solar panels mounted on the X and Y sides. See Figure 1. To achieve the above noted power generation goals, Eagle has been designed with solar panels protruding from the Y sides in a “V” manner, providing for power generation in the satellite’s Z directions as well as the Y directions. See Figure 2. The X side panels will only provide

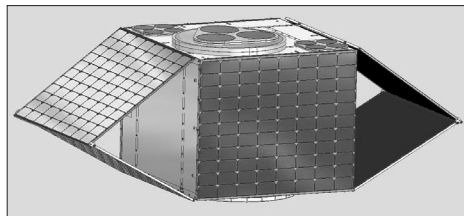


Figure 2: Eagle Y side solar panels opened for orbital operation.

power generation normal to the panels. Thus, Eagle has an all attitude power generating capability.

Panels protruding from the sides of a satellite occupy a significant volume and “footprint” relative to the launch vehicle. As the occupied space on a launch vehicle is costly and precious, the Y-side panels on Eagle have been designed to be deployable into their V shape, thus reducing the launcher footprint and providing a satellite design that is more adaptable for minimal space occupied on a launch vehicle. The deployment aspect of these panels is a matter of concern and is the subject of this article.

A lengthy four years of effort has been expended in trying to prove or disprove this concept of the solar panel deployment for the Eagle spacecraft. This has finally been accomplished through the efforts of Kermit Carlson and later by Fred Parker with his machining of the rather difficult hinges and this author’s assembly and testing of a model of these deployable panels.

Model

The model consists of a vertically mounted MDF (medium density fiberboard) board representing the Y-side of Eagle - in this case of the older, taller design of Eagle. For reference in this model the satellite Z-axis is horizontal with +Z toward the left. See Figure 3.

The solar panels are modeled with representative aluminum bars and foam board centers rather than a complete

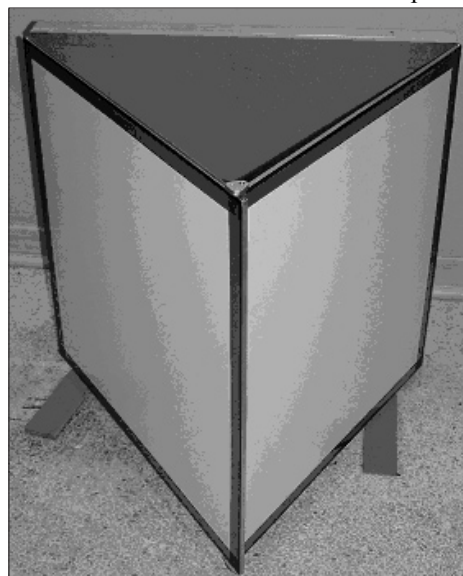


Figure 3: Eagle solar panel deployment test model with the solar panels in the opened position.

honeycomb panel, which would be much stiffer, but this is not considered to be a serious issue for such a model. The pair of flight-design deployment hinges for each panel are made of stainless steel with a common, long hinge pin of 1.6mm diameter music wire running between them that is torsionally pretensioned to provide the force to deploy the panels. The upper panel, to the left as viewed, has machined grooves on each side of the panel, while the lower panel has a pivoting follower block with pins that engage the slots in the sides of the upper panels, thus linking the motions of the two panels. See Figures 4 & 5.

Operation

The motion sequence is as follows: The lower edge of the upper panel is normally constrained by a pyrotechnically released cord; in this case an assistant’s fingers. Once released, the upper panel swings outboard until the lower panel can move outward. Once in motion, the lower panel brings the upper panel back into the final “V” position. One point of concern all along is that of the motion reversal of the upper panel. In the early video display, one can indeed observe this reversal accompanied by some “bouncing” of the upper panel caused by the inertial forces of this reversal.

The first assembly of this model employed both panels of identical size. The deployment of these panels resulted in exacerbated motion dynamics and serious third derivative effects

continued on page 29 ...

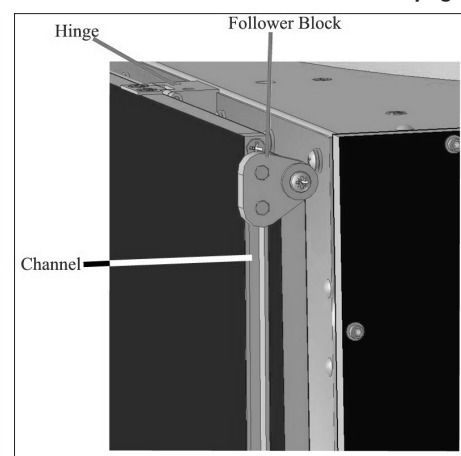
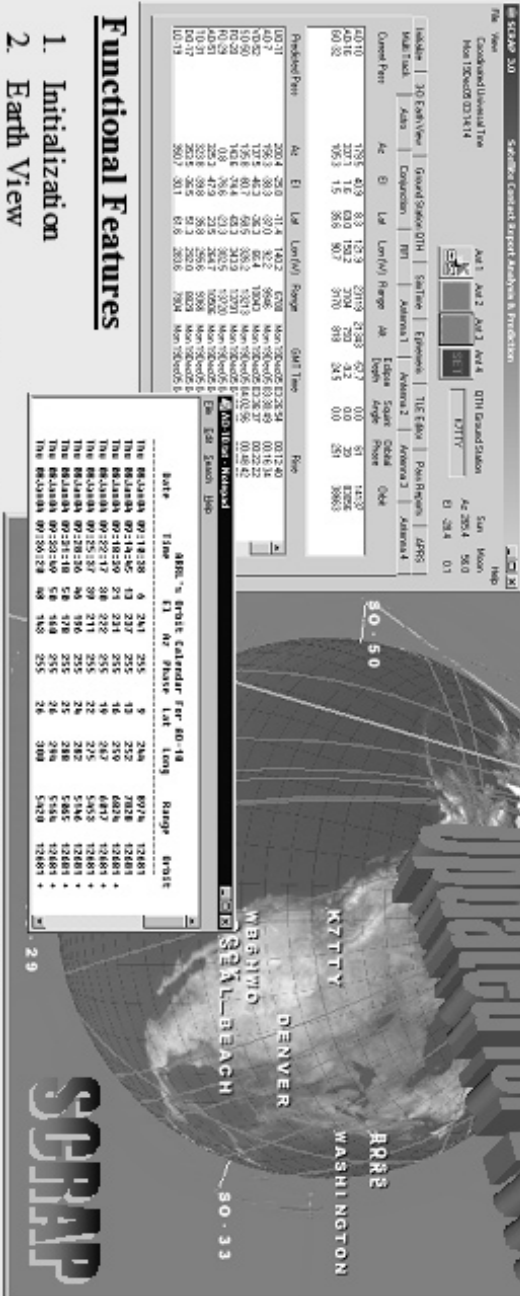


Figure 4: Eagle solar panels in their closed position showing a hinge, a follower block, which pivots on the end of the “lower” panel, and channel machined into the edge of the “upper” panel. Pins, which are located in the follower block, slide in the channel as both panels deploy, thus guiding the follower block and the lower panel as they open.



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AMSAT at Space Day – 2006 at the Smithsonian Air and Space Museum

by Perry Klein, W3PK, w3pk@amsat.org

May 5 was Space Day at the Smithsonian National Air and Space Museum and AMSAT was invited to organize one of eight activities for the thousands of school children, many of them six-graders, visiting that day. Other activities were by NASA-Langley, NASA-JPL, AIAA and a few others.

Many events at the Smithsonian Air and Space Museum are high profile and prestigious. Lockheed Martin underwrote this one, making it possible to keep the Museum open into the evening and for VIP's to be brought in, including John Glenn and other astronauts.

There are now two Smithsonian National Air and Museum locations. One is the Museum on the National Mall, in existence since July 1976, said to receive more visitors than any other museum in the world – over ten million a year. The other is the newer Udvar-Hazy Center, located near Dulles Airport, consisting of two huge hangars, one housing aircraft, the other containing satellites, rockets and the Space Shuttle Enterprise. For the past three years, Space Day has been held at the Udvar-Hazy facility.

The overall objective of Space Day is to raise the awareness and interest of grade school students in space projects, with the hope that more young people will enter professions in engineering and the physical sciences. Education is an important aspect of AMSAT's mission, and our participation in Space Day is one means toward that end.

Another objective is to work cooperatively

with the Smithsonian Institution and their curators. They already have three OSCAR satellites on display. One is the Microsat mechanical test model currently at the National American History Museum. The other two are an OSCAR 1 model from Project OSCAR and a PcSat thermal test model from the U.S. Naval Academy. These two satellites are in a small-satellite display case at the Udvar-Hazy Center. The Curators of the Space History Division are working on a book, to be published in October 2007, to commemorate the 50th anniversary of Sputnik, based on artifacts at the Smithsonian, such as OSCAR 1.

Our exhibit was set up near the small-satellite display case so we could explain the original OSCAR 1 and the more recent PCSat. We had about a dozen AMSAT volunteers helping with our exhibit:

Bob Bruninga, WB4APR, brought a PCSat 2, a demonstration of spin stabilization and several small satellites he is working on with midshipmen at the U.S. Naval Academy.

Bob Bruhns, WA3WDR, of Spacequest and AMRAD brought their "nanosat" and a small solar panel wired to an LED. Kids were able to shine a flashlight onto the panel to show how it produces electric power. He also demonstrated a small optical corner-reflector using an LED pointer to reflect light from the small mirrors.

Frank Bauer, KA3HDO, Bill Boston, N3DCI, Bob McCown, N3IYI, Ken Nichols, KD3VK, Hugh O'Donnell, W3FUO and

Ken Silverman helped explain the ARISS program and Suitsat. Kids were able to listen to a recorded ARISS contact on astronaut headphones.

Paul Shuch, N6TX, and his son Erin flew down in their small airplane and were on hand to explain AMSAT's education program. Martha also was on hand to help explain things to the school children. Art Feller (W4ART) took lots of photos.

We also were able to show off CalPoly's CubeSat model, beautifully mounted in a small Plexiglas case by Dick Daniels, W4PUJ. We explained that CubeSats are being built as student team projects in many universities and that a dozen are due to be launched in June from Russia.

Many thanks to everyone who helped out on Space Day and also to the ARRL and ICOM America for providing hand-out material on Amateur Radio. 📻

More Space Day pictures can be found on page 28 ...



In the background are (l-r) Frank Bauer, Perry Klein and Bill Boston. The Scouts in the foreground are listening to recorded astronaut ARISS communications.



More school children listening to recorded ARISS astronaut communications.

AMSAT at the SVHFS Conference

By Gould Smith, WA4SXM, wa4sxm@amsat.org

The 10th annual SVHFS (Southeast VHF Society) Conference was held in Greenville, SC on April 28 & 29, 2006. AMSAT presentations were made by:

- Tom Clark, K3IO; "Software Defined Transponders" and "Future AMSAT Missions: Phase 3E and Eagle"
- Bob McGwier, N4HY; "The SDR-1000 for VHF, UHF and Microwave"
- Gould Smith, WA4SXM; "Short Wavelength Communications with Amateur Satellites"

Bob, Tom and Rick Hambly, W2GPS demonstrated a working SDX transponder all during the conference, like the one that will fly on EAGLE and P3E.

The folks from RFSpace were displaying the real-time decoded 400 bps beacon in the commercial exhibitors room using their SDR-14 (Software Defined Receiver) and the AO40Rcv software. The 50 kHz wide SDX had a 70cm input and a 2m output. Numerous simultaneous amateur transmissions were visible on a separate computer screen Tom Clark had set up and used as a receiver display.

These VHF conferences are excellent opportunities for AMSAT members to learn more about UHF and microwave design and operation, as well as discuss the synergy between the VHF/UHF/microwave community and the AMSAT community. As the amateur satellite frequencies move higher, the higher frequency groups have a great deal of knowledge and experience to offer those of us less experienced. Excellent presentations were made on antennas, preamps, transverters, amateur satellites and 10GHz rain scatter during the conference. As

with most conferences the biggest benefit is meeting and talking with people of similar interests. You really find out how small the world is and how many of these new friends know many of the people you know.

Noble Laureate Dr. Joe Taylor, K1JT, the author of the WSJT weak signal software, was the banquet speaker and we even got to see his Nobel medal. Interesting results were obtained on homebrew and commercial preamps and antennas from the Noise Figure and Antenna Gain measurements during the conference, some antennas exhibiting negative gain. The Kickoff luncheon on Friday featured new ARRL President Joel Harrison, W5ZN bringing us up to date (as of that week) on BPL activities at the FCC and how the ARRL is working with them for a better solution.

Sunday, the PARI (Pisgah Astronomical Research Institute) site was opened for guided tours for the conference attendees. PARI is a 200 acre site located in a remote part of the Pisgah National Forest. It began as the east coast NASA tracking facility, then was turned over to other government agencies for awhile and in 1999 became a public foundation. It has two 26-meter radio telescopes, a 12.2-meter radio telescope, a 4.6-meter radio telescope and numerous optical telescopes. Many of these can be controlled remotely. There are a number of interesting experiments ongoing at PARI including astronomical, atmospheric, weather and environmental monitoring. Quite an interesting site.

The SVHFS Conference will be in Atlanta next year. The dates are April 27 & 28, 2007 with AMSAT Area Coordinator/member and new SVHFS President Robin Cutshaw, AA4RC, serving as Chairman. Make your plans to be there. SVHFS will be posting many of the 2006 presentations on their Web site at <http://svhfs.org/> This was a very enjoyable and educational weekend. We thank SVHFS for the generous contribution to AMSAT!



Ott Fiebel, W4WSR, President, Southeastern VHF Society, presents a \$300 check to AMSAT. Accepting the check are Rick Hambly, W2GPS, President of AMSAT-NA and Gould Smith, WA4SXM, Director Field Operations. Photo by Tom Clark, K3IO.

More Space Day Pictures

See the article on page 27.



Perry Klein photo

Curator Paul Cerrazi of the Air and Space Museum's Space History Division, holding the CalPoly Cubesat model.



Ken Nichols photo

Frank H. Winter, Air and Space Museum's Curator of Rocketry and his daughter, Elaine with the CalPoly CubeSat model.



Perry Klein photo

Martha demonstrating solar power to some interested attendees.



2006 AMSAT North America Space Symposium

6-8 October 2006, Foster City, California

Call for Papers: First Announcement

<http://www.amsat.org/amsat-new/symposium/2006CallForPapers.php>

Invitation

Speakers are invited to submit and present papers dealing with the science of Amateur Radio satellites and associated technologies for the AMSAT 2006 Space Symposium. The Symposium will be held at the Crowne Plaza Hotel in Foster City, California approximately 10km south of San Francisco International Airport. This is an annual Symposium. However the 2005 Symposium was cancelled due to hurricane damage caused by hurricanes Katrina and Rita. Speakers originally scheduled for the 2005 Symposium are invited to re-submit papers for the 2006 Symposium.

Topics

Recommended topics include but are not limited to the following categories:

- AMSAT P3E
- AMSAT Eagle
- Microsatellite Projects
- Cubesat and Nanosatellite Projects
- ARISS
- Attitude Determination and Control
- Propulsion
- Communications
- Mechanical
- Antennas
- Ground Stations
- Digital Modes
- Education and Outreach
- Launch Opportunities
- Status Reports

Other Activities

The AMSAT Board of Directors will meet on 5-6 October. The AMSAT Annual General Meeting (AGM) will be held on 6 October. AMSAT International will meet 8 October.

The IARU Satellite Committee will meet during the Symposium and will hold a public round table discussion on frequency coordination on 8 October.

The ARISS International Delegates Meeting will be held on 9-10 October "Birds of a Feather" sessions (BOFS) will be available on request.

Deadline

Applications to present papers must be submitted by 15 July 2006. Papers must be submitted no later than 1 August 2006.

Procedure

The planning committee has created an online registration system where you can submit your abstract and track it. Using this system you will allow you to submit your paper and any subsequent changes online. Visit the 2006 Symposium Paper Registration Web page for instructions: <http://www.amsat.org/amsat-new/symposium/2006PapersProcedure.php>

Organizer

Project OSCAR. Contact Emily Clarke, N1DID, for additional information.

Venue

See the 2006 Space Symposium Web page for additional information about the venue.

... Eagle Solar Panel Deployment Report continued from page 25.

of the inertial reversal of the upper panel motion. These dynamics are illustrated in the video, filename "EagleLongPanelDeploy.mov". The video can be obtained from the author.

Second Test

A second configuration was done to model the current design of the Eagle spaceframe in which the two Y-side solar panels are not the same size. This change was by shortening the lower panel so that its Z dimension represents the scaled dimensions of the satellite. The resulting motion provides an initiation of the motion of the lower panel that is more gradual and the inertial reversal of the upper panel is not so abrupt as in the first test, lowering the third derivative motion characteristics. This motion is shown in the video, filename "EagleShortPanelDeploy.mov". This video can be obtained from the author.

Conclusion

These tests leave the observer with the feeling that this deployment model has demonstrated a concept that is worthy of pursuing for Eagle should it prove necessary to achieve the mission AMSAT has chosen for its next spacecraft. ☸

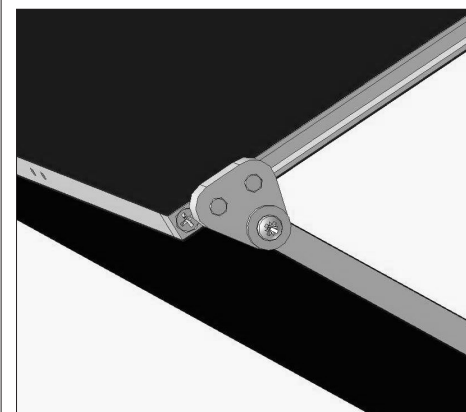


Figure 5: Eagle solar panels that are opened showing follower block having been guided by the pins sliding in channel, keeping the panels together as they open.

Below: Drew Glassbrenner, KO4MA, does his usual yeoman job at demonstrating satellite contacts to the Dayton Hamvention crowd. This year the Hamvention provided us with an excellent location to demonstrate satellite communications just outside our booth area. Rick Hambly (left) looks on.



Photo: WA4SWJ

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2.4 GHz Antenna Comparison

Using the MFJ-1800 2.4 GHz WiFi Antenna for a V/S Mode Downlink Antenna

by Allen Mattis, N5AFV, n5afv@amsat.org

Introduction

When I read the excellent article by Drew Glasbrenner, KO4MA, [1] and the short note by Aruni Perera, VE4WMK, [2] in the July/August 2005 issue of *The AMSAT Journal* regarding operating on AO-51 in V/S mode, I decided that I needed to try this mode. After all, I enjoy operating on the Amateur Radio satellites because I continually learn new things, and using a downconverter and radio wave propagation on 2400 MHz were two areas that I had no experience with. I ordered a K5GNA downconverter with a 2400 MHz dipole and corner reflector (www.k5gna.com) and was soon making contacts on AO-51 when it was in V/S mode.

The K5GNA downconverter with corner reflector is advertised as having 12 dBi gain; however, I had difficulty hearing the downlink when the satellite was below eight degrees elevation. I was looking through the latest MFJ catalog when I noticed a 2.4 GHz 16-element WiFi Yagi with an advertised gain of 15 dBi. The cost for the MFJ-1800 is \$29.95, and I decided to order one to see how it compared to the K5GNA dipole and corner reflector.

Testing the MFJ-1800

When I received the MFJ-1800 antenna, I found that it is actually quite fragile, and the instructions that come with the antenna state “The MFJ-1800 WiFi Yagi Antenna is intended for applications protected from the

elements – out of the weather. It can be made weatherproof by mounting inside a 3-inch PVC pipe.” The MFJ-1800 comes with a standard “N” connector. I used a CABLE-X-PERTS CXP1318FN 3-foot jumper to connect the MFJ-1800 to the K5GNA downconverter.

I was anxious to compare the performance of the antennas to see if the 15 dBi Yagi would outperform the 12 dBi dipole and corner reflector. I used the MFJ-1800 to work three passes of AO-51 when it was in V/S mode. On the first pass (16 degree maximum elevation) I was unable to hear the satellite; however, it was a Sunday evening and AO-51 may not have been switched over to V/S mode until late in the pass. I tried a second pass (35 degree maximum elevation) and had much better results. I could hear the downlink and managed to make four contacts. However, the downlink signals seemed to be weaker than with the dipole and corner reflector and there was considerable fading. I tried a third pass (14 degree maximum elevation) and heard many stations, but was unable to complete a contact. Whenever I called another station, significant fading made it impossible for me to tell if the station I had called answered me.

After this first attempt to use the MFJ-1800 antenna for V/S mode, it was time to re-evaluate my testing of the antenna. I did notice that in the MFJ catalog description

both 15 dB and 15 dBi gain are used to describe the antenna. My very limited use of the MFJ-1800 suggested that it might have less gain than the K5GNA dipole and corner reflector. I discussed the performance of the MFJ-1800 antenna with two friends who have had more experience working with higher frequencies. Both Andy Mac Allister, W5ACM, and Jerry Brown, K5OE, felt that using the 3-foot jumper cable to connect the MFJ-1800 antenna to the K5GNA downconverter might have caused significant signal loss and that it would be better to directly couple the MFJ-1800 antenna to the K5GNA downconverter.

The March 13-19 and May 2-3, 2006 periods of V/S mode on AO-51 provided a good opportunity to test the MFJ-1800 antenna coupled directly to the K5GNA downconverter. I was pleased to find that the MFJ antenna appears to outperform the K5GNA dipole with corner reflector. Using the MFJ-1800 antenna I operated an AO-51 pass with a four degree maximum elevation from the top of a parking garage where I had a clear horizon and made three contacts and on a five degree maximum elevation pass I made one contact. I also tried a pass with a two degree maximum elevation from the same parking garage using the MFJ-1800 antenna and I heard a carrier on the downlink frequency, but was unable to detect any voice or modulation. During an earlier period of V/S operation on AO-51, I operated from the same location on two eight degree maximum elevation passes and struggled to make two and three contacts with the K5GNA dipole and corner reflector. On higher elevation passes I did not observe any significant difference between the two antennas. With either antenna it was common to make five to eight contacts depending on how many people were working the higher elevation passes.

I also observed that it was necessary to rotate the K5GNA dipole with corner reflector quite frequently to compensate for fading of the downlink signal. The MFJ Yagi antenna did not appear to be affected as much by fading and required less rotation. I must also state, however, that the K5GNA dipole with corner reflector is very sturdy and rugged, while the MFJ-1800 antenna is somewhat fragile. Another drawback to using the MFJ-1800 is that it is quite directional, and

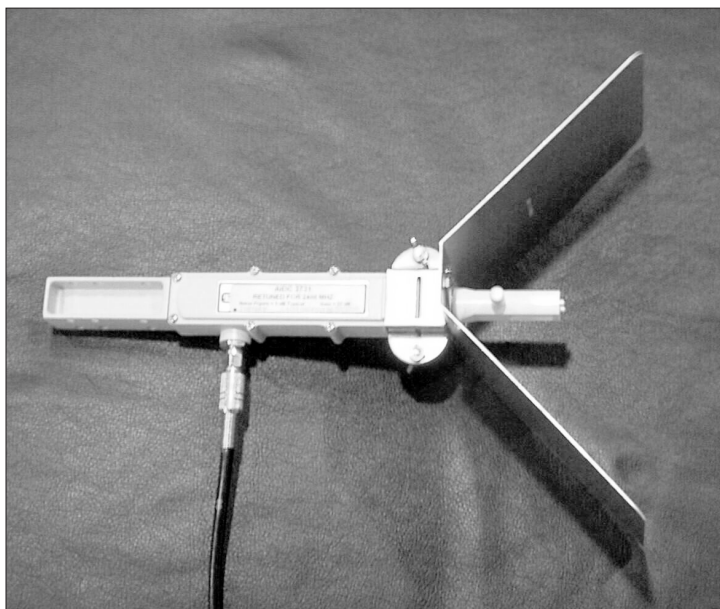


Figure 1: The K5GNA downconverter with 2400 MHz dipole and corner reflector.



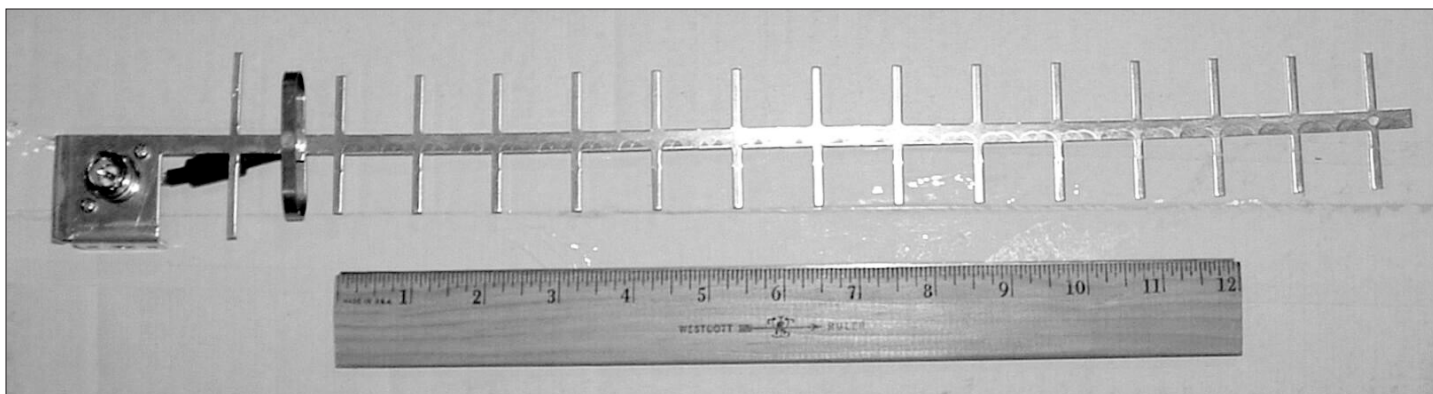


Figure 2: The MFJ-1800 antenna is actually quite fragile and should be mounted inside 3-inch PVC pipe if it is installed where it is exposed to the elements.

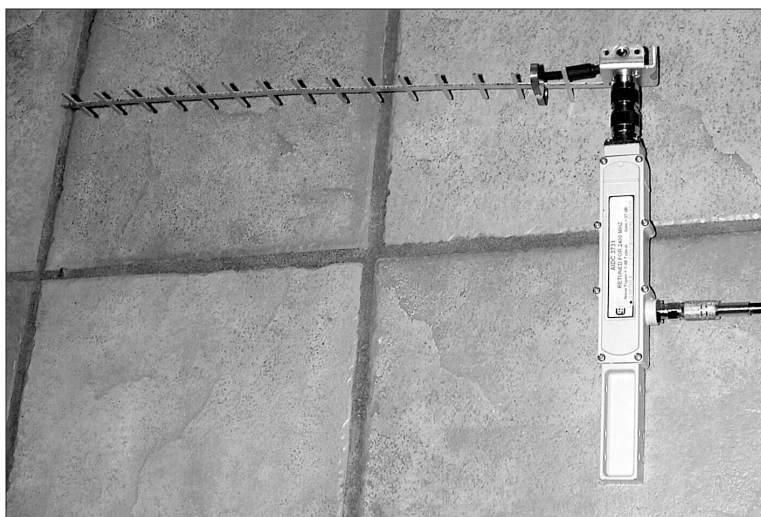


Figure 3: The MFJ-1800 antenna coupled directly to the K5GNA downconverter with an M-M N-connector.

I sometimes lost the bird for short periods of time until I repositioned the antenna to point more directly at the satellite.

Conclusions

The bottom line is that the MFJ-1800 antenna allows me to work lower elevation passes of AO-51 in V/S mode than I can with the K5GNA dipole and corner reflector. The slight difference in performance of the two antennas on high elevation passes may result from the directivity and difficulty aiming the MFJ Yagi directly at the satellite. My purpose in writing this article is to make others aware of this antenna and its possible use in working satellites. After all, experimentation and learning is what satellite and space communications are all about, and we learn from each other.

References

- [1] Glasbrenner, Drew, Mode V/S on AO-51: Something New Under the Sun, *The AMSAT Journal*, July/August 2005, pp. 14-16.
- [2] Perera, Aruni, Field Day Fun in Canada, *The AMSAT Journal*, July/August 2005, p. 22.

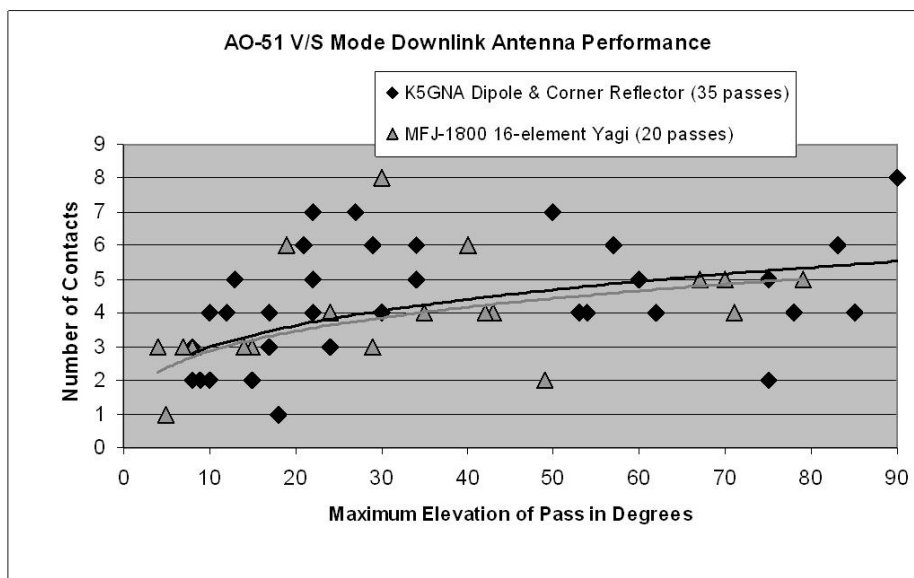
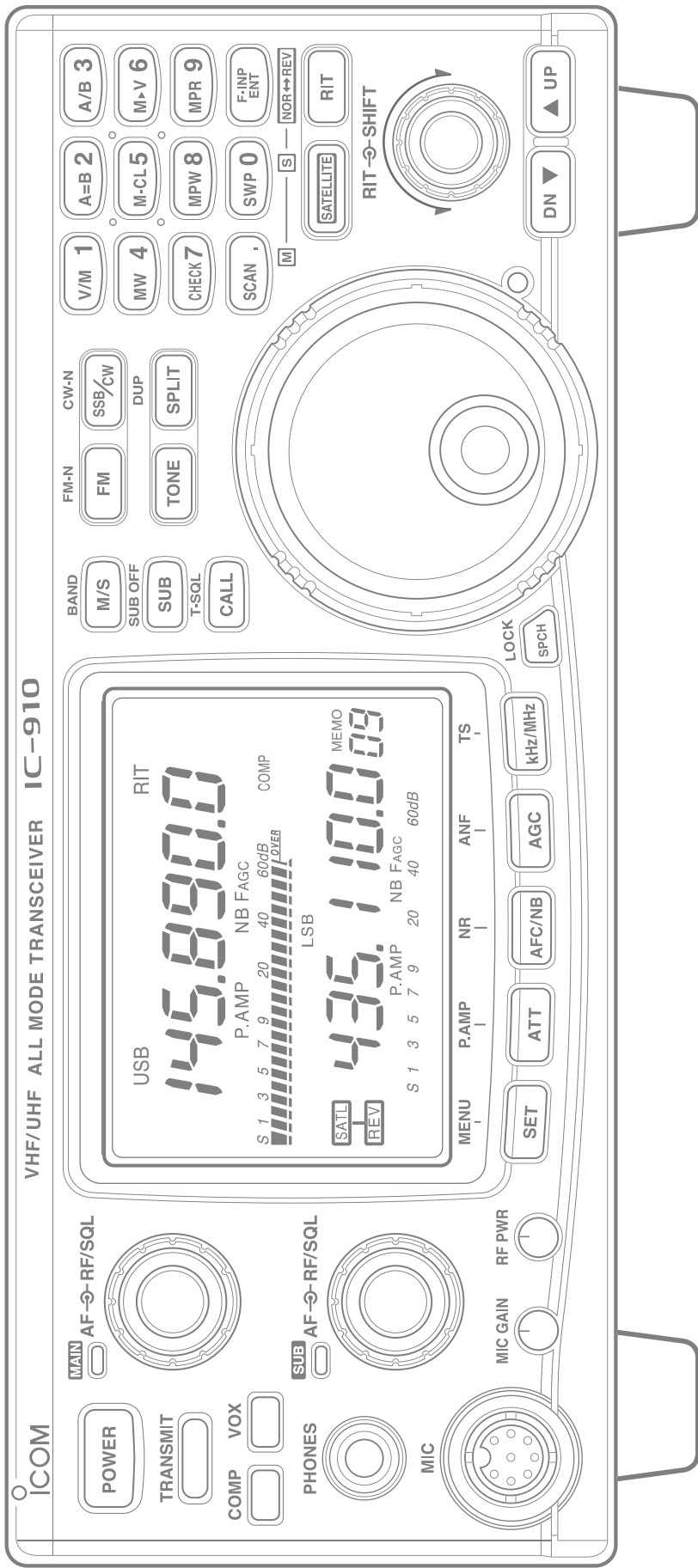


Figure 4: Results of working AO-51 V/S mode using the MFJ-1800 and the K5GNA corner reflector antennas.





910H. Actual Size (Space is infinite. Your shack is not).

Don't let the size fool you, there's never been a rig bred more specifically for satellite ops. A big-screen, dual-frequency readout sets the scene while smooth Doppler compensation lets you follow the action. With .11µV sensitivity and true dual tracking VFO's. Add optional down converters, pre-amps and DSP for an almost complete off-the-shelf system. But the sky is not the limit with the 910H. For terrestrial operation, it more than delivers everything you need. Whether you're working FM repeaters, or tracking the newest satellite, the 910H puts you in command. See your authorized Icom dealer.

- 100W Variable Output • All Mode • Simultaneously Works Two Bands at Once • 9600 bps High Speed PACKET Port • .11 µV Sensitivity • Main & Sub Band Functions for IF Shift, Sweep, NB, RF Attenuator • Large LCD Display • Four Versatile Scanning Functions • CTCSS Encode/Decode/Tone Scan - Even in Satellite Mode! • Built-in Keypad • PC Controllable • Memory Pad • Normal/Reverse Satellite Tracking • Size (approx): 9.5" W x 3.687" H x 9.437" D • Weight: 9.5 lbs.

- AG-2400**
Downlink Receive Converter
Converts a 2400MHz RF signal to a 144MHz IF signal, allowing US mode operation. Use with optional UX-910, for LS mode operation.
- AG-25** 144MHz
AG-35 430MHz
Preamplifiers
External all-weather, mast mounting preamplifiers. Compensates for cable loss.

- UX-910**
1200MHz Band Unit
Turns the IC-910H into an all mode, tri-band transceiver. Also makes crossband and full duplex operation possible.
- UT-106**
DSP Unit
AF-DSP functions, including noise reduction and automatic notch filter. Use two, one for main band & one for sub-band.

Accessories